



US011258163B2

(12) **United States Patent**  
**Froese et al.**

(10) **Patent No.:** **US 11,258,163 B2**  
(45) **Date of Patent:** **Feb. 22, 2022**

(54) **HOUSING AND ANTENNA ARCHITECTURE FOR MOBILE DEVICE**

(71) Applicant: **Apple Inc.**, Cupertino, CA (US)  
(72) Inventors: **Kevin M. Froese**, San Francisco, CA (US); **Paul U. Leutheuser**, Saratoga, CA (US); **Martin J. Auclair**, Campbell, CA (US); **Christopher J. Durning**, Cupertino, CA (US); **Jun Ham**, Cupertino, CA (US); **Lucy E. Browning**, San Francisco, CA (US); **Sawyer I. Cohen**, Menlo Park, CA (US); **Richard Hung Minh Dinh**, Cupertino, CA (US); **Donald J. Parr**, Mountain View, CA (US)

(73) Assignee: **APPLE INC.**, Cupertino, CA (US)  
(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 567 days.

(21) Appl. No.: **16/142,285**  
(22) Filed: **Sep. 26, 2018**

(65) **Prior Publication Data**  
US 2020/0076056 A1 Mar. 5, 2020

**Related U.S. Application Data**  
(60) Provisional application No. 62/725,237, filed on Aug. 30, 2018.

(51) **Int. Cl.**  
**H01Q 1/30** (2006.01)  
**H01Q 1/24** (2006.01)  
(Continued)  
(52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **H01Q 5/30** (2015.01); **H04M 1/0283** (2013.01);  
(Continued)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/243; H01Q 5/30  
See application file for complete search history.

(56) **References Cited**  
U.S. PATENT DOCUMENTS

4,106,839 A 8/1978 Cooper  
4,256,412 A 3/1981 Tybus et al.  
(Continued)

FOREIGN PATENT DOCUMENTS

CN 101087500 12/2007  
CN 102159045 8/2011  
(Continued)

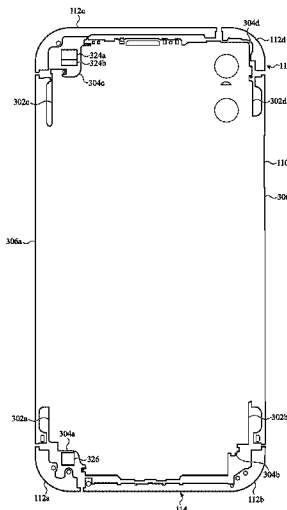
OTHER PUBLICATIONS

Author Unknown, "Improved Touchscreen Products," Research Disclosure, Kenneth Mason Publications, Hampshire, UK, GB, vol. 428, No. 53, Dec. 1, 1999.  
(Continued)

*Primary Examiner* — Graham P Smith  
(74) *Attorney, Agent, or Firm* — Brownstein Hyatt Farber Schreck, LLP

(57) **ABSTRACT**  
A device includes a display and a housing. The housing surrounds the display and has four corners defining portions of an exterior surface of the device. The housing includes a first housing segment defining at least part of a first corner of the four corners and configured to operate as an antenna; a second housing segment defining at least part of a second corner of the four corners; and a third housing segment defining at least part of a third corner of the four corners. The third corner forms part of the housing diagonally opposite the second corner. The housing further includes a non-conductive housing component that structurally couples the first housing segment to another portion of the housing.

**20 Claims, 46 Drawing Sheets**





US011258174B2

(12) **United States Patent**  
**Kim et al.**

(10) **Patent No.:** **US 11,258,174 B2**  
(45) **Date of Patent:** **Feb. 22, 2022**

(54) **ANTENNA RADIATOR INCLUDING PLURALITY OF LAYERS AND ELECTRONIC DEVICE INCLUDING THE SAME**

(56) **References Cited**

U.S. PATENT DOCUMENTS

(71) Applicant: **Samsung Electronics Co., Ltd.**,  
Gyeonggi-do (KR)

6,223,033	B1	4/2001	Lusterman	
9,246,208	B2	1/2016	Qu et al.	
10,707,571	B2	7/2020	Wu	
2004/0051666	A1*	3/2004	Aisenbrey .....	H05K 3/101 343/700 MS

(72) Inventors: **Yoonjung Kim**, Gyeonggi-do (KR);  
**Jaedeok Lim**, Gyeonggi-do (KR);  
**Gyuyeong Cho**, Gyeonggi-do (KR);  
**Hyein Park**, Gyeonggi-do (KR)

2004/0233112	A1	11/2004	Aisenbrey	
2010/0097273	A1	4/2010	Biris et al.	
2015/0278671	A1	10/2015	Martin et al.	

(Continued)

(73) Assignee: **Samsung Electronics Co., Ltd.**,  
Gyeonggi-do (KR)

FOREIGN PATENT DOCUMENTS

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

JP	2017-208665	A	11/2017
KR	10-2011-0080023	A	7/2011
KR	10-2018-0024583	A	3/2018

OTHER PUBLICATIONS

(21) Appl. No.: **16/861,415**

Elliot, et al.; "E-textile Microstrip Patch Antennas for GPS"; Apr. 23, 2012; XP032200215.

(22) Filed: **Apr. 29, 2020**

(Continued)

(65) **Prior Publication Data**  
US 2020/0350682 A1 Nov. 5, 2020

*Primary Examiner* — Graham P Smith  
(74) *Attorney, Agent, or Firm* — Cha & Reiter, LLC

(30) **Foreign Application Priority Data**  
Apr. 30, 2019 (KR) ..... 10-2019-0050482

(57) **ABSTRACT**

(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 9/04** (2006.01)

Disclosed is an electronic device including a housing, a first plate positioned on a front surface of the housing, a second plate positioned on a rear surface of the housing, an antenna radiator interposed between the first plate and the second plate, and a wireless communication circuit connected to the antenna radiator and processing a signal in a specific frequency band. The antenna radiator includes at least one conductive fabric layer having a resistance characteristic suitable for transmitting or receiving the signal in the specific frequency band, and the at least one conductive fabric layer includes a fabric that is plated with at least one metal.

(52) **U.S. Cl.**  
CPC ..... **H01Q 9/0414** (2013.01); **H01Q 1/243** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01G 9/0414; H01G 1/243  
See application file for complete search history.

**20 Claims, 20 Drawing Sheets**





US011258178B2

(12) **United States Patent**  
**Julien et al.**

(10) **Patent No.:** **US 11,258,178 B2**  
(45) **Date of Patent:** **Feb. 22, 2022**

(54) **ANTENNA AND METHOD OF ASSEMBLY OF SUCH ANTENNA**

(71) Applicant: **Nokia Shanghai Bell Co., Ltd.**,  
Shanghai (CN)

(72) Inventors: **Thomas Julien**, Lannion (FR);  
**Jean-Pierre Harel**, Lannion (FR); **Zied Charaabi**, Lannion (FR); **Patrick Lecam**, Lannion (FR); **Jerome Plet**, Lannion (FR)

(73) Assignee: **Nokia Shanghai Bell Co., Ltd.**,  
Shanghai (CN)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 133 days.

(21) Appl. No.: **16/652,446**

(22) PCT Filed: **Oct. 2, 2018**

(86) PCT No.: **PCT/IB2018/057626**  
§ 371 (c)(1),  
(2) Date: **Mar. 31, 2020**

(87) PCT Pub. No.: **WO2019/069216**  
PCT Pub. Date: **Apr. 11, 2019**

(65) **Prior Publication Data**  
US 2020/0235479 A1 Jul. 23, 2020

(30) **Foreign Application Priority Data**  
Oct. 2, 2017 (EP) ..... 17306315

(51) **Int. Cl.**  
**H01Q 9/04** (2006.01)  
**H01Q 21/08** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **H01Q 9/0471** (2013.01); **H01Q 5/40** (2015.01); **H01Q 21/0075** (2013.01); **H01Q 21/08** (2013.01); **H01Q 21/28** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/1242; H01Q 1/246; H01Q 1/42; H01Q 5/10; H01Q 5/40; H01Q 9/0471; H01Q 21/0075; H01Q 21/28; H01Q 21/08  
See application file for complete search history.

(56) **References Cited**  
U.S. PATENT DOCUMENTS

2007/0236317 A1 10/2007 Cheng et al.  
2012/0299799 A1 11/2012 Chiu et al.

FOREIGN PATENT DOCUMENTS

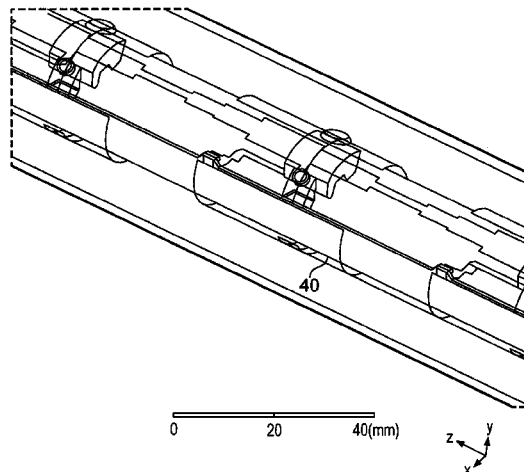
CN 102394342 A 3/2012  
CN 203134968 U 8/2013  
TW 575979 B 2/2004

OTHER PUBLICATIONS

International Search Report for PCT/IB2018/057626 dated Jan. 30, 2019.

*Primary Examiner* — Robert Karacsony  
(74) *Attorney, Agent, or Firm* — Fay Sharpe LLP

(57) **ABSTRACT**  
An antenna comprising: a longitudinal support member for supporting components of the antenna and a method of assembling such an antenna is disclosed. The components supported by the longitudinal member comprise: at least one signal feed probe configured to capacitively supply a signal to a corresponding at least one radiating patch; the at least one radiating patch mounted to at least partially wraparound the longitudinal support member; and signal supply circuitry for supplying a signal to the at least one signal feed. The signal supply circuitry is mounted on an outer surface of the inner longitudinal support member; and the longitudinal  
(Continued)





US011258180B2

(12) **United States Patent**  
**Schultz**

(10) **Patent No.:** **US 11,258,180 B2**

(45) **Date of Patent:** **Feb. 22, 2022**

(54) **FOIL ANTENNA**

(71) Applicant: **FUBA Automotive Electronics GmbH**,  
Bad Salzdetfurth (DE)

(72) Inventor: **Micha Schultz**, Bad Salzdetfurth (DE)

(73) Assignee: **FUBA Automotive Electronics GmbH**

(\* ) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 296 days.

(21) Appl. No.: **16/661,621**

(22) Filed: **Oct. 23, 2019**

(65) **Prior Publication Data**

US 2020/0136259 A1 Apr. 30, 2020

(30) **Foreign Application Priority Data**

Oct. 23, 2018 (DE) ..... 102018126361.9

(51) **Int. Cl.**  
**H01Q 9/28** (2006.01)  
**H01Q 1/32** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 9/285** (2013.01); **H01Q 1/32**  
(2013.01)

(58) **Field of Classification Search**

CPC ..... H01G 1/32; H01G 9/285  
See application file for complete search history.

(56) **References Cited**

**FOREIGN PATENT DOCUMENTS**

DE	3306054	A1	8/1984
DE	60007254	T2	9/2004
WO	8908973	A1	9/1989
WO	9624963	A1	8/1996
WO	9629756	A1	9/1996
WO	2004025778	A1	3/2004
WO	2012118636	A2	9/2012

**OTHER PUBLICATIONS**

Search Report regarding related DE Application No. 102018126361.9; dated Oct. 1, 2019; 9 pgs.

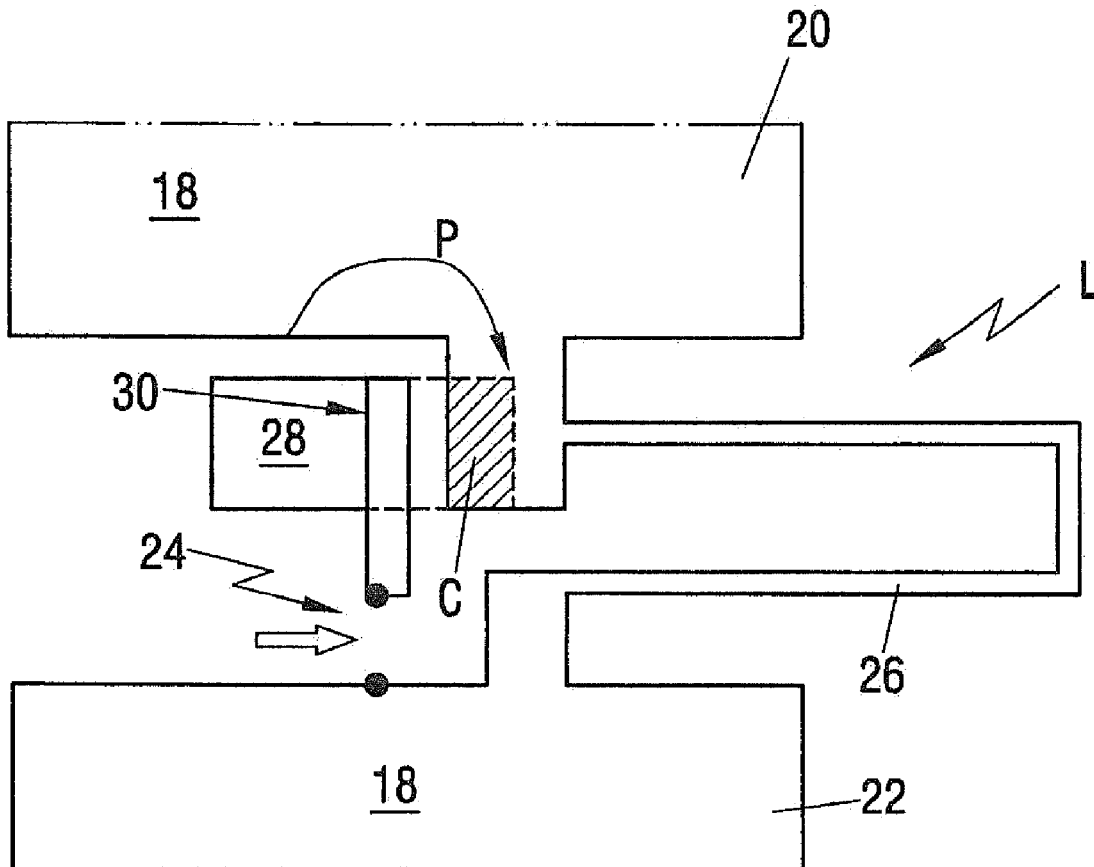
*Primary Examiner* — Graham P Smith

(74) *Attorney, Agent, or Firm* — Dickinson Wright PLLC

(57) **ABSTRACT**

A film antenna comprises an antenna element having a first electrically conductive layer and an adaptation network that is formed by a second conductive layer.

**16 Claims, 2 Drawing Sheets**





(12) **United States Patent**  
**Kim et al.**

(10) **Patent No.:** **US 11,258,184 B2**  
(45) **Date of Patent:** **Feb. 22, 2022**

(54) **ANTENNA SYSTEM INCLUDING A POLYMER COMPOSITION HAVING A LOW DISSIPATION FACTOR**

USPC ..... 343/702  
See application file for complete search history.

(71) Applicant: **Ticona LLC**, Florence, KY (US)  
(72) Inventors: **Young Shin Kim**, Cincinnati, OH (US);  
**Xinyu Zhao**, Cincinnati, OH (US)  
(73) Assignee: **Ticona LLC**, Florence, KY (US)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,162,466 A 7/1979 Hunsinger et al.  
4,458,039 A 7/1984 Eickman  
(Continued)

FOREIGN PATENT DOCUMENTS

CN 104961916 A 10/2015  
CN 104961922 A 10/2015  
(Continued)

OTHER PUBLICATIONS

Young Shin Kim, U.S. Appl. No. 17/178,318, filed Feb. 18, 2021,  
Polymer Composition for Use in an Antenna System.  
(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 9 days.

(21) Appl. No.: **16/995,870**

(22) Filed: **Aug. 18, 2020**

(65) **Prior Publication Data**

US 2021/0057827 A1 Feb. 25, 2021

**Related U.S. Application Data**

(60) Provisional application No. 63/056,842, filed on Jul. 27, 2020, provisional application No. 63/038,959, filed on Jun. 15, 2020, provisional application No. 63/024,557, filed on May 14, 2020, provisional application No. 63/008,979, filed on Apr. 13, 2020, provisional application No. 62/994,314, filed on Mar. 25, 2020, provisional application No. 62/972,195, filed on Feb. 10, 2020, provisional application No. 62/951,039, filed on Dec. 20, 2019, provisional  
(Continued)

*Primary Examiner* — Peguy Jean Pierre

(74) *Attorney, Agent, or Firm* — Dority & Manning, P.A.

(57) **ABSTRACT**

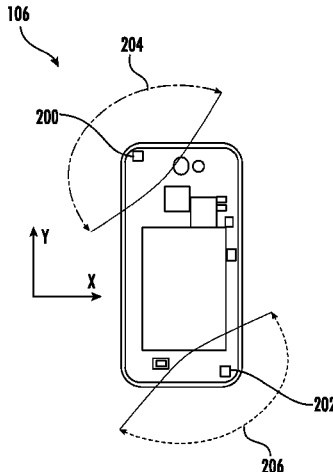
A 5G antenna system is disclosed that comprises a substrate and at least one antenna element configured to transmit and receive 5G radio frequency signals. The at least one antenna element is coupled to the substrate. The substrate comprises a polymer composition that comprises a polymer matrix containing at least one polymer having a glass transition temperature of about 30° C. or more and at least one laser activatable additive wherein the polymer composition exhibits a dissipation factor of about 0.1 or less, as determined at a frequency of 2 GHz.

(51) **Int. Cl.**  
**H01Q 1/38** (2006.01)  
**H01Q 21/00** (2006.01)  
**H01Q 21/06** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 21/0087** (2013.01); **H01Q 1/38** (2013.01); **H01Q 21/0012** (2013.01); **H01Q 21/065** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 21/0087; H01Q 1/38

**36 Claims, 7 Drawing Sheets**





US011264692B2

(12) **United States Patent**  
**Itou**

(10) **Patent No.:** **US 11,264,692 B2**

(45) **Date of Patent:** **Mar. 1, 2022**

(54) **ANTENNA UNIT**

(71) Applicant: **Yazaki Corporation**, Tokyo (JP)

(72) Inventor: **Eita Itou**, Shizuoka (JP)

(73) Assignee: **YAZAKI CORPORATION**, Tokyo (JP)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/669,464**

(22) Filed: **Oct. 30, 2019**

(65) **Prior Publication Data**

US 2020/0144694 A1 May 7, 2020

(30) **Foreign Application Priority Data**

Nov. 2, 2018 (JP) ..... JP2018-207132

(51) **Int. Cl.**

**H01Q 1/38** (2006.01)  
**H01Q 1/12** (2006.01)  
**H01P 3/08** (2006.01)  
**H01Q 1/48** (2006.01)  
**H01Q 9/04** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H01Q 1/12** (2013.01); **H01P 3/081** (2013.01); **H01Q 1/48** (2013.01); **H01Q 9/045** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 1/12; H01Q 1/48; H01Q 9/045; H01Q 1/22; H01Q 9/0407; H01Q 1/38; H01Q 1/1221; H01Q 1/405; H01Q 1/42; H01Q 1/50; H01Q 1/32; H01Q 1/40; H01P 3/081

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,798,734 A \* 8/1998 Ohtsuka ..... H01Q 9/0414 343/700 MS  
6,002,370 A \* 12/1999 Mckinnon ..... H01Q 1/38 343/700 MS  
6,362,786 B1 3/2002 Asano et al.  
2011/0057853 A1 \* 3/2011 Kim ..... H01Q 1/48 343/843  
2013/0229299 A1 9/2013 Matsuzawa et al.  
2017/0104275 A1 \* 4/2017 Yanagisawa ..... H01Q 9/38

FOREIGN PATENT DOCUMENTS

CN 202189889 U 4/2012  
CN 103004017 A 3/2013  
CN 107078395 A 8/2017  
EP 0 697 139 A 3/2017  
JP 61-284102 A 12/1986  
JP 05243836 A \* 9/1993  
JP 2013-58893 A 3/2013  
JP 2017-63364 A 3/2017  
WO 95/24746 A1 9/1995  
WO 2015/200754 A1 12/2015

\* cited by examiner

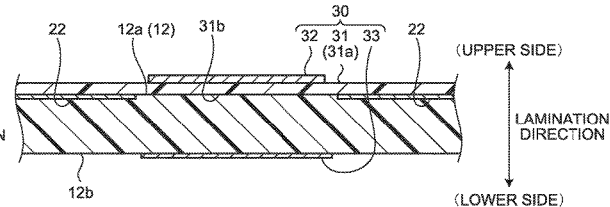
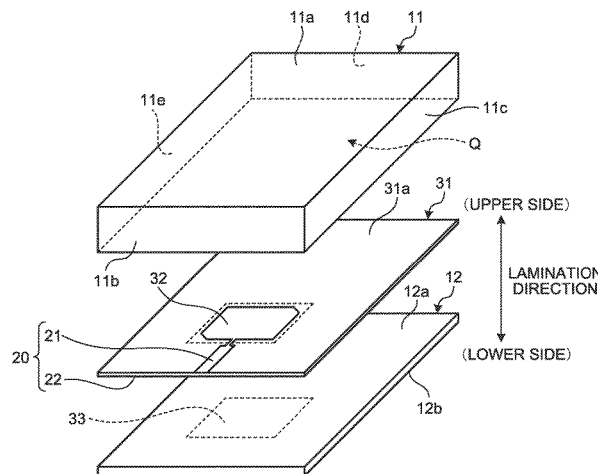
*Primary Examiner* — Dieu Hien T Duong

(74) *Attorney, Agent, or Firm* — Kenealy Vaidya LLP

(57) **ABSTRACT**

An antenna unit includes a patch antenna and a case. The patch antenna includes a conductive antenna pattern and an antenna ground pattern that functions as ground of the antenna pattern and receives an electric wave. The case has dielectricity, the case being provided with the patch antenna. The antenna pattern is provided on an inner wall surface of a wall portion of the case. The antenna ground pattern is provided on an outer wall surface of a wall portion of the case and is positioned so as to face the antenna pattern.

**2 Claims, 5 Drawing Sheets**





US011264699B2

(12) **United States Patent**  
**Chang et al.**

(10) **Patent No.:** **US 11,264,699 B2**  
(45) **Date of Patent:** **Mar. 1, 2022**

(54) **ANTENNA STRUCTURE AND MOBILE DEVICE**

(71) Applicant: **Wistron NeWeb Corp.**, Hsinchu (TW)

(72) Inventors: **Cheng-Pang Chang**, Hsinchu (TW);  
**Shih-Hsien Tseng**, Hsinchu (TW)

(73) Assignee: **WISTRON NEWEB CORP.**, Hsinchu (TW)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 228 days.

(21) Appl. No.: **16/658,353**

(22) Filed: **Oct. 21, 2019**

(65) **Prior Publication Data**

US 2020/0185813 A1 Jun. 11, 2020

(30) **Foreign Application Priority Data**

Dec. 7, 2018 (TW) ..... 107144086

(51) **Int. Cl.**

**H01Q 1/24** (2006.01)  
**H01Q 1/22** (2006.01)  
**H01Q 1/48** (2006.01)  
**H01Q 9/42** (2006.01)  
**H01Q 9/40** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H01Q 1/2266** (2013.01); **H01Q 1/2291** (2013.01); **H01Q 1/48** (2013.01); **H01Q 9/40** (2013.01); **H01Q 9/42** (2013.01)

(58) **Field of Classification Search**

None  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

10,056,696 B2 \* 8/2018 Tseng ..... H01Q 13/106  
10,297,907 B2 \* 5/2019 Chen ..... H01Q 1/243  
2013/0113671 A1 5/2013 Su et al.  
2015/0118710 A1 \* 4/2015 Govindappa ..... C12P 21/02  
435/69.4  
2016/0049719 A1 \* 2/2016 Tseng ..... H01Q 5/371  
343/702  
2017/0005414 A1 \* 1/2017 Yang ..... H01Q 5/378  
2017/0033467 A1 \* 2/2017 Huang ..... H01Q 5/357

(Continued)

FOREIGN PATENT DOCUMENTS

TW 201320468 A1 5/2013  
TW 201703350 A 1/2017

*Primary Examiner* — Trinh V Dinh

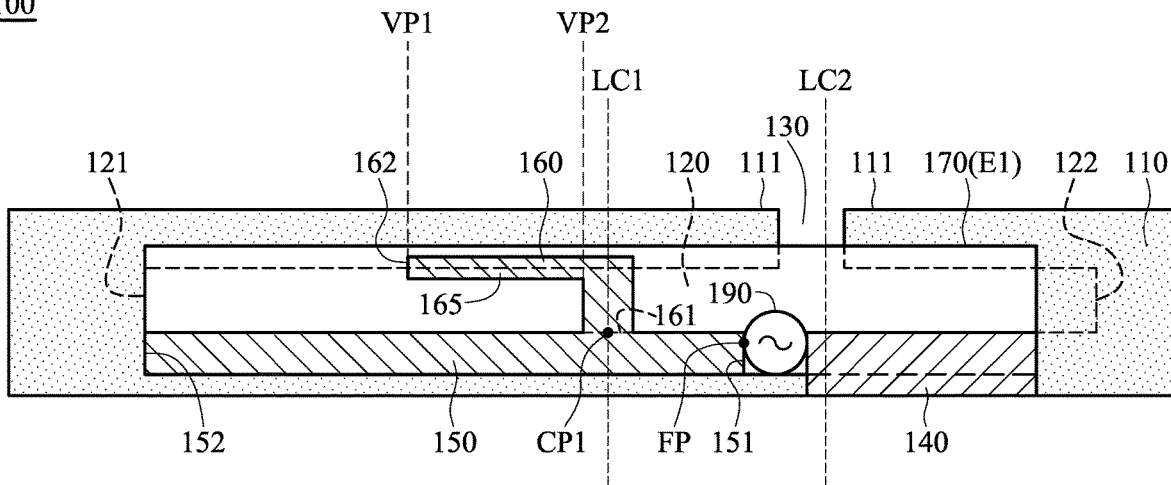
(74) *Attorney, Agent, or Firm* — McClure, Qualey & Rodack, LLP

(57) **ABSTRACT**

An antenna structure includes a metal mechanism element, a ground element, a first radiation element, a second radiation element, and a dielectric substrate. The metal mechanism element has a slot. A notch is formed on an edge of the metal mechanism element. The notch and the slot are connected to each other. The ground element is coupled to the metal mechanism element. The first radiation element has a feeding point. The second radiation element is coupled to the first radiation element and includes a first extension portion. The second radiation element extends across the slot. The first extension portion is parallel to the slot. A vertical projection of the first extension portion at least partially overlaps the slot. The dielectric substrate is adjacent to the metal mechanism element. The first radiation element and the second radiation element are disposed on the dielectric substrate.

**20 Claims, 8 Drawing Sheets**

100





US011264718B2

(12) **United States Patent**  
**Yang**

(10) **Patent No.:** **US 11,264,718 B2**

(45) **Date of Patent:** **Mar. 1, 2022**

(54) **EIGHT-FREQUENCY BAND ANTENNA**

(56) **References Cited**

(71) Applicant: **Taoglas Group Holdings Limited**, San Diego, CA (US)

U.S. PATENT DOCUMENTS

(72) Inventor: **Tsai Yi Yang**, Tainan (TW)

6,198,442 B1	3/2001	Rutkowski et al.
6,323,811 B1	11/2001	Tsubaki et al.
6,380,895 B1	4/2002	Moren et al.
6,693,604 B2	2/2004	Washiro et al.
7,183,980 B2	2/2007	Chang et al.
7,557,759 B2	7/2009	Lin et al.

(73) Assignee: **TAOGLAS GROUP HOLDINGS LIMITED**, Enniscorthy (IE)

(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **16/685,843**

CA	2887126 A1 *	4/2014	.....	H01Q 5/10
CN	1485950	3/2004		

(Continued)

(22) Filed: **Nov. 15, 2019**

*Primary Examiner* — Dameon E Levi

*Assistant Examiner* — Jennifer F Hu

(65) **Prior Publication Data**

(74) *Attorney, Agent, or Firm* — Garson & Gutierrez, PC

US 2020/0266541 A1 Aug. 20, 2020

**Related U.S. Application Data**

(57) **ABSTRACT**

(63) Continuation of application No. 16/172,098, filed on Oct. 26, 2018, now Pat. No. 10,483,644, which is a continuation of application No. 14/948,237, filed on Nov. 20, 2015, now abandoned.

An eight-frequency band antenna includes a carrier, a high-frequency segment, a low-frequency segment, a printed circuit board (PCB) and an inductor. The high-frequency segment is arranged on left side of the carrier and the low-frequency segment is arranged on right side of the carrier. The radiator on the bottom face of the carrier electrically connects with the micro strip of the PCB and the ground line of the ground metal when the carrier is fixed to the PCB. Moreover, the low-frequency segment is corresponding to a metal face with smaller area such that the low-frequency segment is at a free space to enhance the frequency response of the low-frequency segment and the bandwidth of the high-frequency segment. The area and the volume of blind hole on the carrier can adjust the effective dielectric constant to adjust the resonant frequency and bandwidth of the antenna.

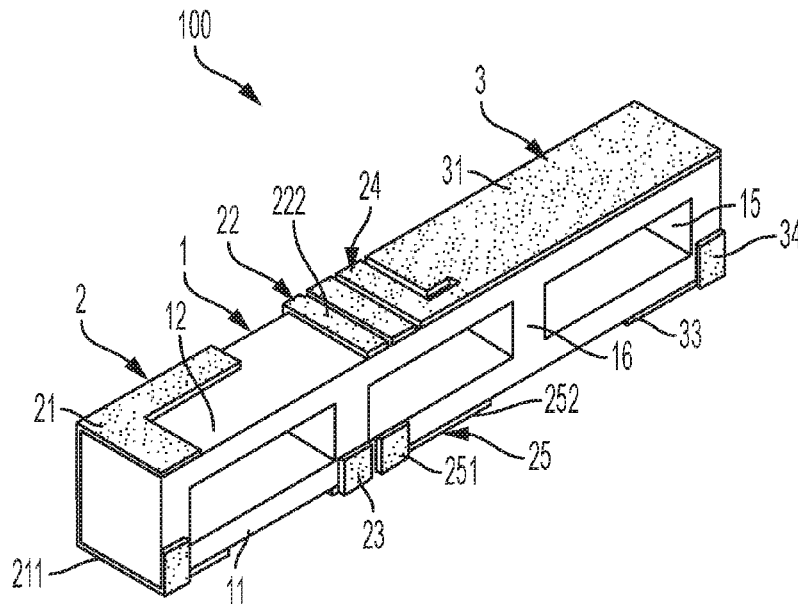
(51) **Int. Cl.**  
**H01Q 5/371** (2015.01)  
**H01Q 1/24** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 5/371** (2015.01); **H01Q 1/243** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 5/10; H01Q 5/30; H01Q 5/307; H01Q 5/342; H01Q 5/357; H01Q 5/364; H01Q 5/371; H01Q 1/48; H01Q 1/243; H01Q 9/04; H01Q 1/38

See application file for complete search history.

**14 Claims, 9 Drawing Sheets**







US011264721B2

(12) **United States Patent**  
**Nguyen**

(10) **Patent No.:** **US 11,264,721 B2**

(45) **Date of Patent:** **Mar. 1, 2022**

(54) **ANTENNA, CONFIGURATION METHOD OF ANTENNA AND WIRELESS COMMUNICATION DEVICE**

(56) **References Cited**

U.S. PATENT DOCUMENTS

(71) Applicant: **NEC CORPORATION**, Tokyo (JP)

6,288,677 B1 \* 9/2001 Fink ..... H01Q 9/0435  
343/700 MS

(72) Inventor: **Tung Nguyen**, Tokyo (JP)

6,531,984 B1 \* 3/2003 Johannisson ..... H01Q 1/38  
343/700 MS

(73) Assignee: **NEC CORPORATION**, Tokyo (JP)

(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 72 days.

FOREIGN PATENT DOCUMENTS

JP 1-29083 B2 6/1989  
JP 2-179008 A 7/1990

(Continued)

(21) Appl. No.: **16/497,550**

(22) PCT Filed: **Feb. 7, 2018**

OTHER PUBLICATIONS

(86) PCT No.: **PCT/JP2018/004123**

Notice of Reasons for Refusal dated Nov. 17, 2020 from the Japanese Patent Office in Application No. 2019-552297.

§ 371 (c)(1),

(2) Date: **Sep. 25, 2019**

(Continued)

(87) PCT Pub. No.: **WO2018/179870**

*Primary Examiner* — Tung X Le

PCT Pub. Date: **Oct. 4, 2018**

(74) *Attorney, Agent, or Firm* — Sughrue Mion, PLLC

(65) **Prior Publication Data**

US 2021/0111490 A1 Apr. 15, 2021

(57) **ABSTRACT**

(30) **Foreign Application Priority Data**

Mar. 28, 2017 (JP) ..... JP2017-063248

One end of a second feeding line is connected to a first feeding line configured to transmit a first polarization at a first position and the other end is connected to a patch at a second position. One end of a third feeding line is connected to the first feeding line and the other end is connected to the patch at a third position. One end of a fourth feeding line is connected to the patch at a fourth position and configured to transmit a second polarization, wavelengths of the first and second polarizations being the same as each other. The second and third feeding lines are configured to cause the first polarization at the second position to be in opposite phase to the first polarization at the third position. A distance between the second and fourth positions is equal to a distance between the third and fourth positions.

(51) **Int. Cl.**

**H01Q 9/04** (2006.01)

(52) **U.S. Cl.**

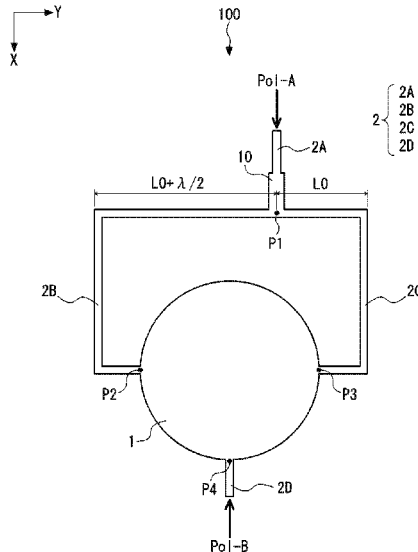
CPC ..... **H01Q 9/045** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 1/523; H01Q 5/357; H01Q 9/045;  
H01Q 9/0485; H01Q 21/065; H01Q  
21/24

See application file for complete search history.

**12 Claims, 15 Drawing Sheets**





US011264722B2

(12) **United States Patent**  
**Etani**

(10) **Patent No.:** **US 11,264,722 B2**

(45) **Date of Patent:** **Mar. 1, 2022**

(54) **ANTENNA**

(71) Applicant: **FURUNO ELECTRIC CO., LTD.**,  
Hyogo (JP)

(72) Inventor: **Soichiro Etani**, Minoh (JP)

(73) Assignee: **FURUNO ELECTRIC CO., LTD.**,  
Hyogo (JP)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 19 days.

(21) Appl. No.: **17/070,944**

(22) Filed: **Oct. 15, 2020**

(65) **Prior Publication Data**

US 2021/0044025 A1 Feb. 11, 2021

**Related U.S. Application Data**

(63) Continuation of application No. PCT/JP2019/011325, filed on Mar. 19, 2019.

(30) **Foreign Application Priority Data**

Apr. 17, 2018 (JP) ..... JP2018-079058

(51) **Int. Cl.**

**H01Q 13/08** (2006.01)  
**H01Q 13/24** (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ..... **H01Q 13/08** (2013.01); **H01Q 1/38** (2013.01); **H01Q 5/378** (2015.01); **H01Q 13/24** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 5/35; H01Q 9/045; H01Q 5/378; H01Q 1/38; H01Q 13/08; H01Q 13/24  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,153,600 A 10/1992 Metzler et al.  
5,410,323 A 4/1995 Kuroda  
(Continued)

FOREIGN PATENT DOCUMENTS

CN 112602234 A \* 4/2021 ..... H01Q 5/385  
JP S63106206 7/1988  
(Continued)

OTHER PUBLICATIONS

“International Search Report (Form PCT/ISA/210)” of PCT/JP2019/011325, dated May 7, 2019, with English translation thereof, pp. 1-2.

*Primary Examiner* — Graham P Smith

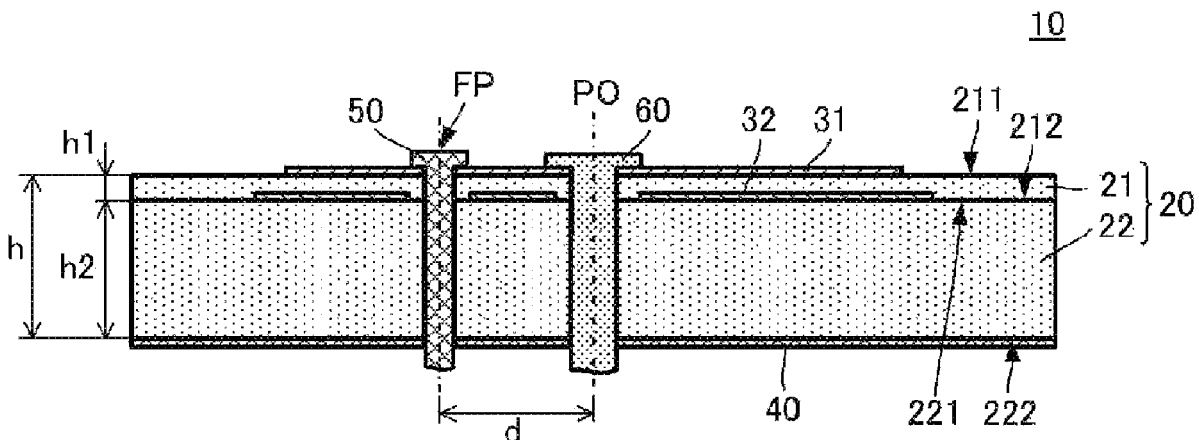
*Assistant Examiner* — Jae K Kim

(74) *Attorney, Agent, or Firm* — JCIPRNET

(57) **ABSTRACT**

An antenna is provided, including: a first substrate, having a first and a second surfaces parallel to each other and having a dielectric; a second substrate, having a third and a fourth surfaces parallel to each other, the third surface being disposed to face and abut the second surface, having a dielectric; a first radiation conductor, formed on the first surface; a second radiation conductor, formed on the third surface; and a power supply, supplying power to the first and second radiation conductors. A position of the power supply is disposed from centers of the first and second radiation conductors by distance  $d$ . A distance between a position where a reflection loss with respect to the second high-frequency signal becomes the smallest and the centers is  $d_0$ ,  $d/d_0$  is equal to or larger than  $4/3$ .

**5 Claims, 5 Drawing Sheets**





US011264723B2

(12) **United States Patent**  
**Wu et al.**

(10) **Patent No.:** **US 11,264,723 B2**

(45) **Date of Patent:** **Mar. 1, 2022**

(54) **SLOT ANTENNAS**

(71) Applicant: **Hewlett-Packard Development Company, L.P.**, Spring, TX (US)

(72) Inventors: **Shih Huang Wu**, Spring, TX (US);  
**Kuan-Ting Wu**, Taipei (TW)

(73) Assignee: **Hewlett-Packard Development Company, L.P.**, Spring, TX (US)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 99 days.

(21) Appl. No.: **16/754,970**

(22) PCT Filed: **Nov. 15, 2017**

(86) PCT No.: **PCT/US2017/061656**  
§ 371 (c)(1),  
(2) Date: **Apr. 9, 2020**

(87) PCT Pub. No.: **WO2019/098998**  
PCT Pub. Date: **May 23, 2019**

(65) **Prior Publication Data**  
US 2020/0303825 A1 Sep. 24, 2020

(51) **Int. Cl.**  
**H01Q 13/10** (2006.01)  
**H01Q 1/24** (2006.01)  
**H01Q 1/52** (2006.01)  
**H01Q 13/18** (2006.01)  
**H01Q 9/28** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 13/10** (2013.01); **H01Q 1/242** (2013.01); **H01Q 1/528** (2013.01); **H01Q 9/28** (2013.01); **H01Q 13/18** (2013.01)

(58) **Field of Classification Search**

CPC ..... **H01Q 13/10**; **H01Q 13/18**; **H01Q 1/242**;  
**H01Q 9/28**; **H01Q 1/528**  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

7,595,759	B2	9/2009	Schlub	
8,223,082	B2	7/2012	Chiang et al.	
8,325,096	B2	12/2012	Ayala et al.	
8,665,164	B2*	3/2014	Hill	H01Q 5/342 343/767
9,484,621	B2	11/2016	Fahlgren et al.	
9,634,378	B2	4/2017	Golko et al.	
2010/0321255	A1	12/2010	Kough	
2013/0194138	A1	8/2013	Hammond	
2016/0294045	A1	10/2016	Shiu et al.	

**OTHER PUBLICATIONS**

Lee, C-T., Low-cost, Direct-fed Slot Antenna Built in Metal Cover of Notebook Computer for 2.4-/5.2-/5.8-ghz WLAN Operation, Mar. 7, 2017, <http://ieeexplore.ieee.org/document/7873296/>.

\* cited by examiner

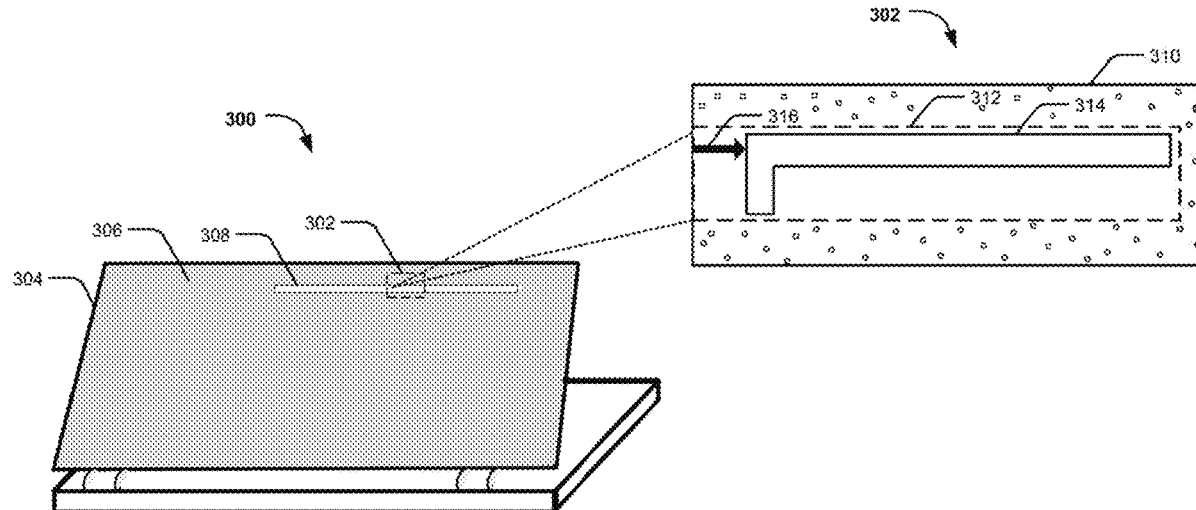
*Primary Examiner* — Joseph J Lauture

(74) *Attorney, Agent, or Firm* — HPI Patent Department

(57) **ABSTRACT**

Examples of slot antennas are described herein. In an example, the slot antenna includes a substrate and an antenna element disposed on the substrate to transmit and receive signals. The substrate is porous.

**12 Claims, 4 Drawing Sheets**





US011264725B2

(12) **United States Patent**  
**Wang et al.**

(10) **Patent No.:** **US 11,264,725 B2**  
(45) **Date of Patent:** **Mar. 1, 2022**

(54) **ANTENNA APPARATUS AND TERMINAL**

(71) Applicant: **Huawei Technologies Co., Ltd.**,  
Shenzhen (CN)

(72) Inventors: **Hanyang Wang**, Reading (GB);  
**Chien-Ming Lee**, Shanghai (CN);  
**Xuefei Zhang**, Shenzhen (CN); **Lijun**  
**Ying**, Shanghai (CN); **Liang Xue**,  
Shanghai (CN); **Jiaqing You**, Shanghai  
(CN); **Lei Wang**, Shanghai (CN); **Yue**  
**Shi**, Shenzhen (CN); **Dong Yu**,  
Shanghai (CN); **Guoping Wu**,  
Shenzhen (CN); **Bo Huang**, Shanghai  
(CN)

(73) Assignee: **HUAWEI TECHNOLOGIES CO.,**  
**LTD.**, Shenzhen (CN)

(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 224 days.

(21) Appl. No.: **16/067,500**

(22) PCT Filed: **Dec. 31, 2015**

(86) PCT No.: **PCT/CN2015/100065**  
§ 371 (c)(1),  
(2) Date: **Jun. 29, 2018**

(87) PCT Pub. No.: **WO2017/113270**  
PCT Pub. Date: **Jul. 6, 2017**

(65) **Prior Publication Data**  
US 2019/0027830 A1 Jan. 24, 2019

(51) **Int. Cl.**  
**H01Q 13/18** (2006.01)  
**H01Q 1/50** (2006.01)  
(Continued)

(52) **U.S. Cl.**

CPC ..... **H01Q 13/18** (2013.01); **H01Q 1/243**  
(2013.01); **H01Q 1/38** (2013.01); **H01Q 1/50**  
(2013.01);

(Continued)

(58) **Field of Classification Search**

CPC ..... H01Q 5/328; H01Q 5/314; H01Q 5/371;  
H01Q 1/50; H01Q 1/38; H01Q 13/18;  
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,209,790 A \* 6/1980 Newcomb ..... H01Q 9/32  
343/830  
5,246,438 A \* 9/1993 Langberg ..... A61B 18/08  
600/374

(Continued)

FOREIGN PATENT DOCUMENTS

CN 1808768 A 7/2006  
CN 101084604 A 12/2007

(Continued)

OTHER PUBLICATIONS

Foreign Communication From A Counterpart Application, Euro-  
pean Application No. 15911898.3, Extended European Search Report  
dated Jan. 16, 2019, 16 pages.

(Continued)

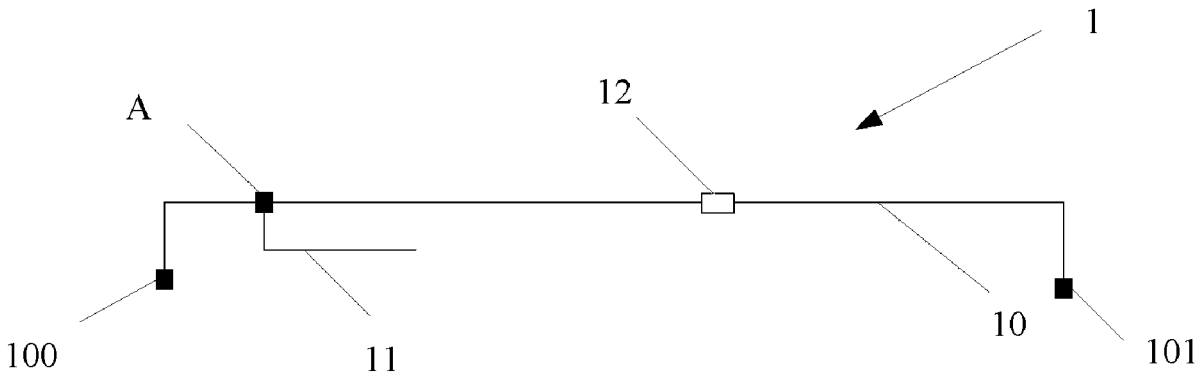
*Primary Examiner* — Graham P Smith  
*Assistant Examiner* — Jae K Kim

(74) *Attorney, Agent, or Firm* — Conley Rose, P.C.

(57) **ABSTRACT**

An antenna apparatus and a terminal, where the antenna  
apparatus includes an antenna body and at least one stub,  
where a feed terminal is disposed on the antenna body, one  
end of the stub is electrically coupled to a coupling point  
between the feed terminal and a first open-circuit end of the  
antenna body, and the other end of the stub is an open-circuit

(Continued)





US011264730B2

(12) **United States Patent**  
**Thompson, Jr. et al.**

(10) **Patent No.:** **US 11,264,730 B2**  
(45) **Date of Patent:** **Mar. 1, 2022**

(54) **QUAD-PORT RADIATING ELEMENT**

(71) Applicant: **Amphenol Antenna Solutions, Inc.**,  
Rockford, IL (US)

(72) Inventors: **James E. Thompson, Jr.**, Mooresville,  
NC (US); **Mark W. Kishler**, Lenoir,  
NC (US); **Jodie M. Bell**, Tallahassee, FL  
(US); **Joshua W. Shehan**, Melbourne,  
FL (US); **Kostyantyn Semonov**,  
Denver, NC (US); **Ryan M. Nagel**,  
Hickory, NC (US); **James C. Carson**,  
Newton, NC (US)

(73) Assignee: **Amphenol Antenna Solutions, Inc.**,  
Rockford, IL (US)

(\* ) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 244 days.

(21) Appl. No.: **16/452,133**

(22) Filed: **Jun. 25, 2019**

(65) **Prior Publication Data**

US 2020/0006862 A1 Jan. 2, 2020

**Related U.S. Application Data**

(60) Provisional application No. 62/690,570, filed on Jun.  
27, 2018.

(51) **Int. Cl.**

**H01Q 21/06** (2006.01)  
**H01Q 21/00** (2006.01)  
**H01Q 9/30** (2006.01)  
**H04B 7/0413** (2017.01)

(52) **U.S. Cl.**

CPC ..... **H01Q 21/061** (2013.01); **H01Q 9/30**  
(2013.01); **H01Q 21/0006** (2013.01); **H01Q**  
**21/0031** (2013.01); **H04B 7/0413** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 21/26; H01Q 9/40  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,730,195 A \* 3/1988 Phillips ..... H01Q 9/18  
343/727  
2003/0030591 A1\* 2/2003 Gipson ..... H01Q 9/30  
343/792  
2004/0160380 A1\* 8/2004 Simpson ..... H01Q 1/242  
343/850

(Continued)

FOREIGN PATENT DOCUMENTS

CN 105789888 A 7/2016

OTHER PUBLICATIONS

International Search Report Issued in PCT/US2019/039012 dated  
Nov. 5, 2019.

(Continued)

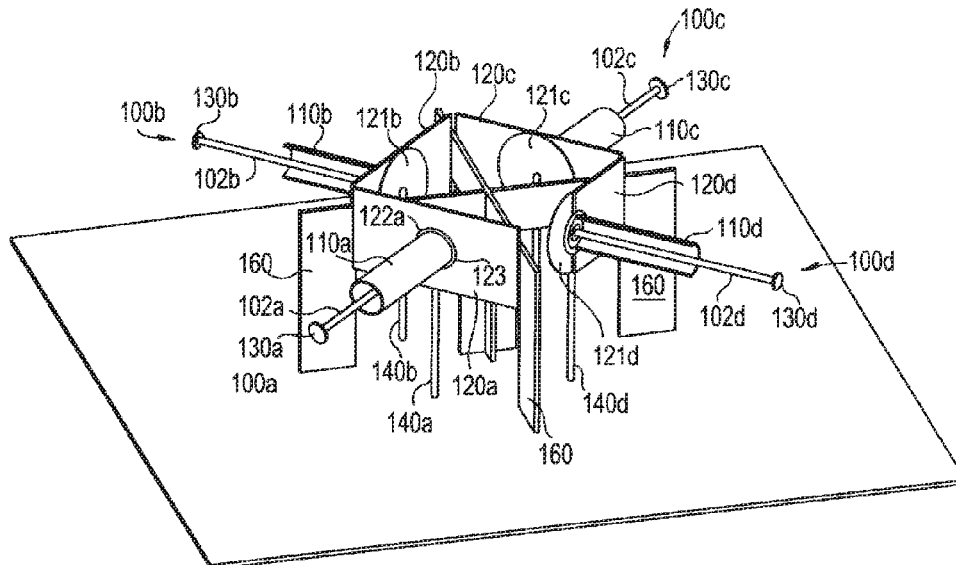
*Primary Examiner* — Ricardo I Magallanes

(74) *Attorney, Agent, or Firm* — Blank Rome LLP

(57) **ABSTRACT**

An Antenna Radiating Element provides 4 simultaneous  
isolated radiation ports that can be used to increase the  
orders of MIMO communication for wireless applications.  
An antenna array that contains a plurality of the Quad-Port  
Radiating Elements (QPRE). An antenna that contains mul-  
tiple arrays of the QPRE in single-band or Multi-Band  
configurations that produces 2x the available polarization  
states without the need to increase the antenna aperture or  
reduce the size of the antenna array.

**7 Claims, 12 Drawing Sheets**





US011264734B2

(12) **United States Patent**  
**Lee et al.**

(10) **Patent No.:** **US 11,264,734 B2**  
(45) **Date of Patent:** **Mar. 1, 2022**

(54) **ANTENNA AND ELECTRONIC DEVICE INCLUDING SAME**

(71) Applicant: **Samsung Electronics Co., Ltd.,**  
Suwon-si (KR)

(72) Inventors: **Sungyoung Lee, Suwon-si (KR);**  
**Sanghun Park, Suwon-si (KR);**  
**Gunwoo Lee, Suwon-si (KR); Jongjoo**  
**Je, Suwon-si (KR)**

(73) Assignee: **Samsung Electronics Co., Ltd.,**  
Suwon-si (KR)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 8 days.

(21) Appl. No.: **16/971,526**

(22) PCT Filed: **Jul. 31, 2020**

(86) PCT No.: **PCT/KR2020/010157**

§ 371 (c)(1),  
(2) Date: **Aug. 20, 2020**

(87) PCT Pub. No.: **WO2021/025393**

PCT Pub. Date: **Feb. 11, 2021**

(65) **Prior Publication Data**

US 2021/0218128 A1 Jul. 15, 2021

(30) **Foreign Application Priority Data**

Aug. 2, 2019 (KR) ..... 10-2019-0094589

(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 1/42** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **H01Q 21/08** (2013.01); **H01Q 1/243**  
(2013.01); **H01Q 1/38** (2013.01); **H01Q**  
**21/062** (2013.01); **H01Q 21/065** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/24; H01Q 1/243; H01Q 5/307;  
H01Q 9/0407; H01Q 1/12; H01Q 1/1221;  
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

10,003,679 B2 6/2018 Lee et al.  
10,386,790 B2 8/2019 Katsuda et al.  
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2018-105666 A 7/2018  
KR 10-2010-0076452 A 7/2010  
(Continued)

OTHER PUBLICATIONS

International Search Report dated Nov. 10, 2020, issued in International Application No. PCT/KR2020/010157.

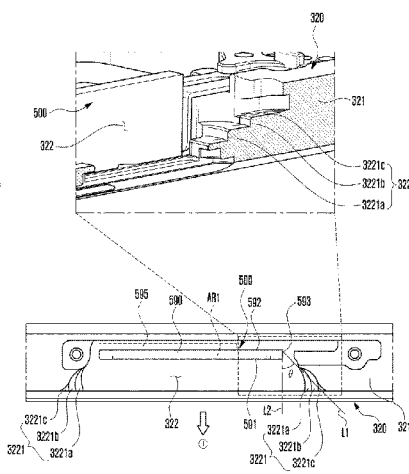
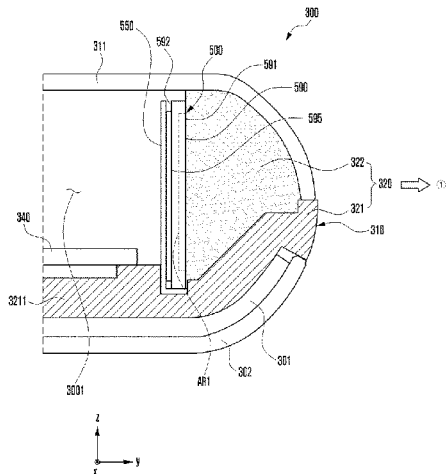
*Primary Examiner* — Thai Pham

(74) *Attorney, Agent, or Firm* — Jefferson IP Law, LLP

(57) **ABSTRACT**

According to various embodiments, an electronic device may include: a housing including a side member including a conductive member and a non-conductive member coupled with the conductive member; and at least one antenna structure disposed in an internal space of the housing and including a substrate disposed to face the side member, and at least one antenna element which is disposed on the substrate such that a beam pattern is formed through the non-conductive member in a direction in which the side member faces, wherein: when the side member is viewed from the outside, a boundary region between the conductive member and the non-conductive member is disposed in a region not overlapping the substrate; in the boundary region, the conductive member includes at least one concave part formed to at least partially receive the non-conductive member; and the at least one concave part includes two or more stepped parts which gradually get higher or lower as

(Continued)





US011271285B2

(12) **United States Patent**  
**Chen et al.**

(10) **Patent No.:** **US 11,271,285 B2**  
(45) **Date of Patent:** **Mar. 8, 2022**

(54) **ANTENNA STRUCTURE**

(71) Applicant: **Shenzhen Next Generation Communications Limited**, Shenzhen (CN)

(72) Inventors: **Jia Chen**, Shenzhen (CN); **Kuo-Cheng Chen**, New Taipei (TW); **Jian-Wei Chang**, New Taipei (TW); **Zhen-Chang Tang**, Shenzhen (CN); **Bo Peng**, Shenzhen (CN); **Wei-Yu Ye**, Shenzhen (CN); **Chun-Sheng Wu**, New Taipei (TW)

(73) Assignee: **Mobile Drive Netherlands B.V.**, Amsterdam (NL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 88 days.

(21) Appl. No.: **16/568,981**

(22) Filed: **Sep. 12, 2019**

(65) **Prior Publication Data**  
US 2020/0091589 A1 Mar. 19, 2020

(30) **Foreign Application Priority Data**  
Sep. 13, 2018 (CN) ..... 201811070579.3

(51) **Int. Cl.**  
**H01Q 1/24** (2006.01)  
**H01Q 5/30** (2015.01)  
**H01Q 5/10** (2015.01)  
**H01Q 21/30** (2006.01)  
**H01Q 13/10** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **H01Q 5/10** (2015.01); **H01Q 5/30** (2015.01); **H01Q 13/10** (2013.01); **H01Q 21/30** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 1/243; H01Q 5/30; H01Q 5/10; H01Q 13/10; H01Q 1/241; H01Q 1/242; H01Q 1/38; H01Q 13/22; H01Q 15/167; H01Q 21/30  
See application file for complete search history.

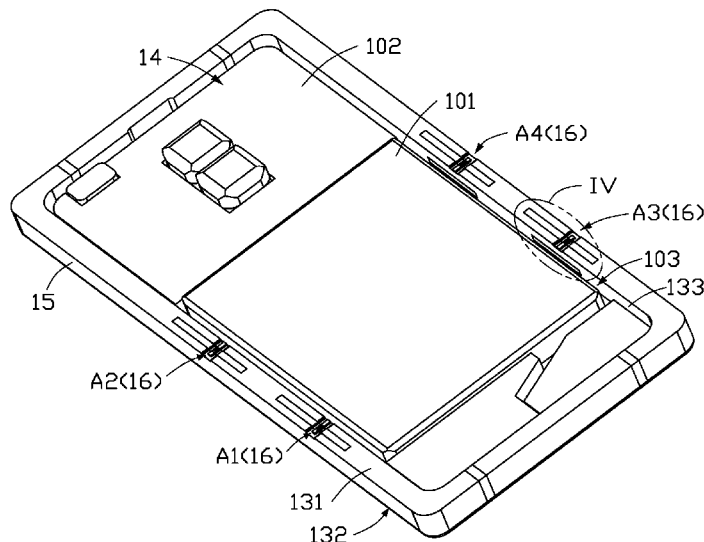
(56) **References Cited**  
**U.S. PATENT DOCUMENTS**  
10,498,041 B1 \* 12/2019 Lin ..... H01Q 13/18  
2010/0156728 A1 \* 6/2010 Alvey ..... H01Q 13/10  
343/702  
2015/0236426 A1 \* 8/2015 Zhu ..... H01Q 1/2266  
343/702  
2017/0309993 A1 \* 10/2017 Tu ..... H01Q 13/10

**FOREIGN PATENT DOCUMENTS**  
CN 103545611 A 1/2014  
CN 107834171 3/2018  
CN 108281753 A 7/2018

\* cited by examiner  
*Primary Examiner* — Andrea Lindgren Baltzell  
*Assistant Examiner* — Yonchan J Kim  
(74) *Attorney, Agent, or Firm* — ScienBiziP, P.C.

(57) **ABSTRACT**  
An antenna structure includes a metal frame. The metal frame includes a first surface, a second surface, and a third surface. The third surface is located between the first surface and the second surface. The metal frame includes at least one antenna. The at least one antenna includes a first gap, a second gap, and a feed portion. The first gap is disposed between the first surface and the second surface. The second gap is disposed in the third surface. The feed portion is mounted on the first surface and spans the first gap. When the feed portion supplies an electric current, the electric current is coupled to the first gap and the second gap.

**20 Claims, 6 Drawing Sheets**





US011271286B2

(12) **United States Patent**  
**Liu et al.**

(10) **Patent No.:** **US 11,271,286 B2**  
(45) **Date of Patent:** **Mar. 8, 2022**

(54) **METAL SHIELDING COVER SLOT ANTENNA AND ELECTRONIC DEVICE**

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/38** (2013.01); **H01Q 13/10** (2013.01); **H01Q 21/28** (2013.01)

(71) Applicant: **ESPRESSIF SYSTEMS (SHANGHAI) CO., LTD.**, Pudong New Area Shanghai (CN)

(58) **Field of Classification Search**  
CPC ..... H01G 1/243; H01G 1/38; H01G 13/10; H01G 21/28  
See application file for complete search history.

(72) Inventors: **Fei Liu**, Pudong New Area Shanghai (CN); **Swee Ann Teo**, Pudong New Area Shanghai (CN)

(56) **References Cited**

(73) Assignee: **ESPRESSIF SYSTEMS (SHANGHAI) CO., LTD.**, Pudong New Area Shanghai (CN)

U.S. PATENT DOCUMENTS

6,573,869 B2\* 6/2003 Moore ..... H01Q 1/243 343/700 MS  
2012/0157175 A1 6/2012 Golko et al.

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

FOREIGN PATENT DOCUMENTS

CN 104505574 A 4/2015  
CN 104518280 A 4/2015

(21) Appl. No.: **16/630,560**

(Continued)

(22) PCT Filed: **Aug. 15, 2018**

OTHER PUBLICATIONS

(86) PCT No.: **PCT/CN2018/100671**

PCT/CN2018/100671, International Search Report dated Nov. 1, 2018.

§ 371 (c)(1),

(2) Date: **Jan. 13, 2020**

*Primary Examiner* — Graham P Smith

(74) *Attorney, Agent, or Firm* — Meunier Carlin & Curfman LLC

(87) PCT Pub. No.: **WO2019/034085**

PCT Pub. Date: **Feb. 21, 2019**

(57) **ABSTRACT**

(65) **Prior Publication Data**

US 2021/0091455 A1 Mar. 25, 2021

Disclosed is a metal shielding cover slot antenna, which includes a metal shielding cover. The metal shielding cover includes a plurality of conductive surfaces, and the metal shielding cover further includes: a slot, an antenna feed terminal and an antenna ground portion. The slot is disposed in at least one of the plurality of conductive surfaces of the metal shielding cover; the antenna ground portion is formed by at least one of the plurality of conductive surfaces, formed by a cut in at least one of the plurality of conductive surfaces or connected to at least one of the plurality of conductive surfaces; the antenna feed terminal is formed by a cut in at least one of the plurality of conductive surfaces

(30) **Foreign Application Priority Data**

Aug. 15, 2017 (CN) ..... 201710697038.2

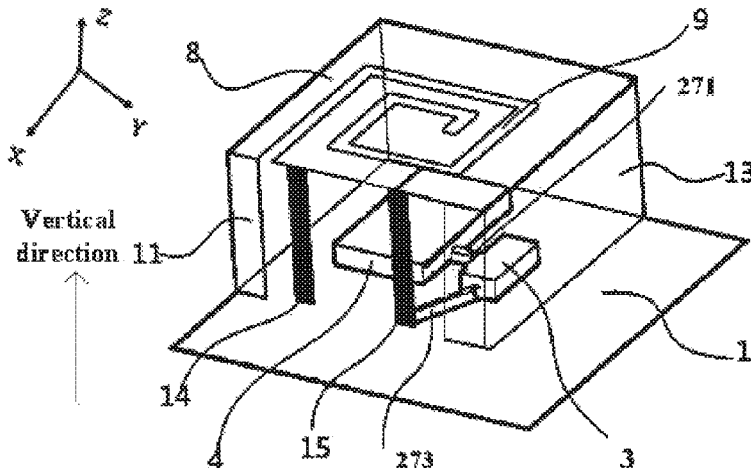
(Continued)

(51) **Int. Cl.**

**H01Q 1/38** (2006.01)

**H01Q 1/24** (2006.01)

(Continued)







US011271287B2

(12) **United States Patent**  
**Andujar Linares et al.**

(10) **Patent No.:** **US 11,271,287 B2**

(45) **Date of Patent:** **\*Mar. 8, 2022**

(54) **WIRELESS DEVICE AND ANTENNA SYSTEM WITH EXTENDED BANDWIDTH**

(71) Applicant: **Fractus Antennas, S.L.**, Barcelona (ES)

(72) Inventors: **Aurora Andujar Linares**, Barcelona (ES); **Jaume Anguera Pros**, Vinaros (ES); **Carles Puente Baliarda**, Barcelona (ES)

(73) Assignee: **IGNION, S.L.**, Barcelona (ES)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 6 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **16/733,842**

(22) Filed: **Jan. 3, 2020**

(65) **Prior Publication Data**

US 2020/0144700 A1 May 7, 2020

**Related U.S. Application Data**

(63) Continuation of application No. 15/621,792, filed on Jun. 13, 2017, now Pat. No. 10,601,110.

(Continued)

(51) **Int. Cl.**

**H01Q 1/24** (2006.01)

**H01Q 1/36** (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/36** (2013.01); **H01Q 5/335** (2015.01); **H01Q 5/371** (2015.01);

(Continued)

(58) **Field of Classification Search**

CPC ..... H01Q 1/243; H01Q 1/36; H01Q 5/335; H01Q 5/371; H01Q 5/40; H01Q 9/0421; H01Q 9/42

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,274,340 B2 9/2007 Ozden et al.

7,688,276 B2 3/2010 Quintero Illera et al.

(Continued)

FOREIGN PATENT DOCUMENTS

EP 2978069 A1 1/2016

EP 3073568 A1 9/2016

(Continued)

OTHER PUBLICATIONS

Andujar, A., et al., "Ground Plane Boosters as a Compact Antenna Technology for Wireless Handheld Devices", IEE Transactions on Antennas and Propagation, May 2011, pp. 1668-1677, vol. 59, No. 5.

(Continued)

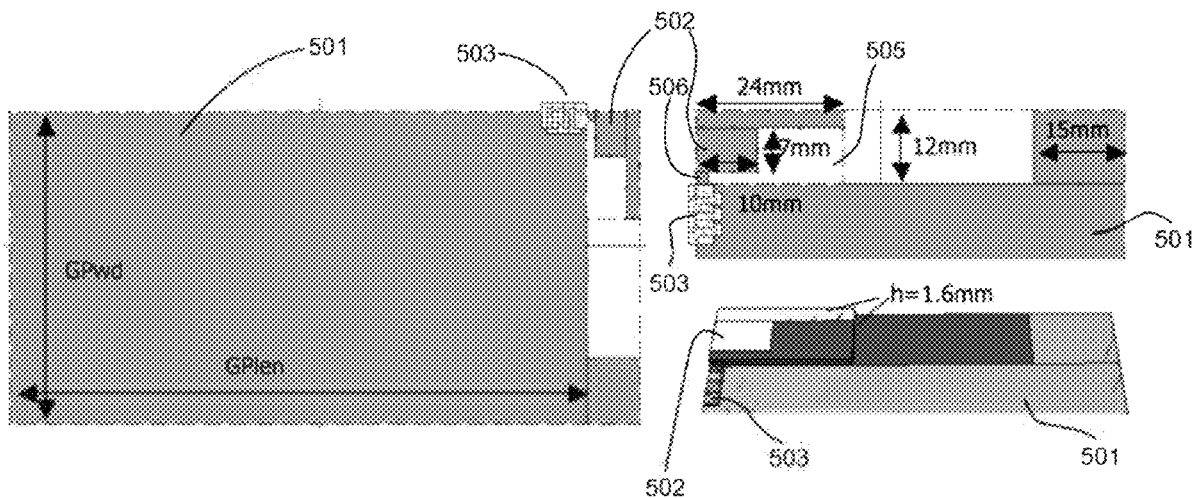
Primary Examiner — Hoang V Nguyen

(74) Attorney, Agent, or Firm — Edell, Shapiro & Finnan, LLC

(57) **ABSTRACT**

An apparatus comprises an antenna element operable in multiple frequency bands and configured to be connected to a ground plane and to a radiofrequency system to provide impedance matching at the multiple frequency bands, where the radiofrequency system comprising at least a matching network. A maximum length of the antenna element is shorter than  $L/12$  but longer than  $L/22$ , where  $L$  is the free-space wavelength corresponding to a lowest frequency related to a lowest frequency region of operation of the antenna element. A contour of the antenna element has a complexity factor  $F12$  less than 1.25.

**15 Claims, 3 Drawing Sheets**





US011271288B2

(12) **United States Patent**  
**Ke**

(10) **Patent No.:** **US 11,271,288 B2**  
(45) **Date of Patent:** **Mar. 8, 2022**

(54) **METAL MIDDLE FRAME,  
MILLIMETER-WAVE ANTENNA  
STRUCTURE, AND MOBILE TERMINAL**

(71) Applicant: **BEIJING XIAOMI MOBILE  
SOFTWARE CO., LTD.**, Beijing (CN)

(72) Inventor: **Changqing Ke**, Beijing (CN)

(73) Assignee: **BEIJING XIAOMI MOBILE  
SOFTWARE CO., LTD.**, Beijing (CN)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 56 days.

(21) Appl. No.: **16/818,492**

(22) Filed: **Mar. 13, 2020**

(65) **Prior Publication Data**

US 2021/0135336 A1 May 6, 2021

(30) **Foreign Application Priority Data**

Oct. 30, 2019 (CN) ..... 201911043880.X

(51) **Int. Cl.**

**H04Q 1/24** (2006.01)  
**H04M 1/02** (2006.01)  
**H01Q 1/42** (2006.01)  
**H01Q 1/24** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/421** (2013.01); **H04M 1/026** (2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 13/16; H01Q 1/243; H01Q 1/421; H01Q 21/064; H01Q 21/08; H01Q 21/28; H04M 1/026  
USPC ..... 455/453, 575.1, 575.5, 575.7; 342/702  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2002/0027528 A1\* 3/2002 Okabe ..... H01Q 13/106 343/702  
2016/0111789 A1\* 4/2016 Chang ..... H01Q 1/243 343/702  
2018/0041238 A1\* 2/2018 Jiang ..... B29C 45/14639  
2019/0214706 A1\* 7/2019 Kim ..... G06F 1/1626  
2020/0044346 A1\* 2/2020 Gu ..... H01Q 5/328  
2020/0295461 A1\* 9/2020 Luk ..... H01Q 9/045  
2020/0358198 A1\* 11/2020 Hsu ..... H01Q 5/328

(Continued)

FOREIGN PATENT DOCUMENTS

EP 3149805 A1 4/2017  
EP 3293824 A1 3/2018

(Continued)

OTHER PUBLICATIONS

Extended European search report of counterpart EP application No. 20164514.0 dated Sep. 25, 2020.

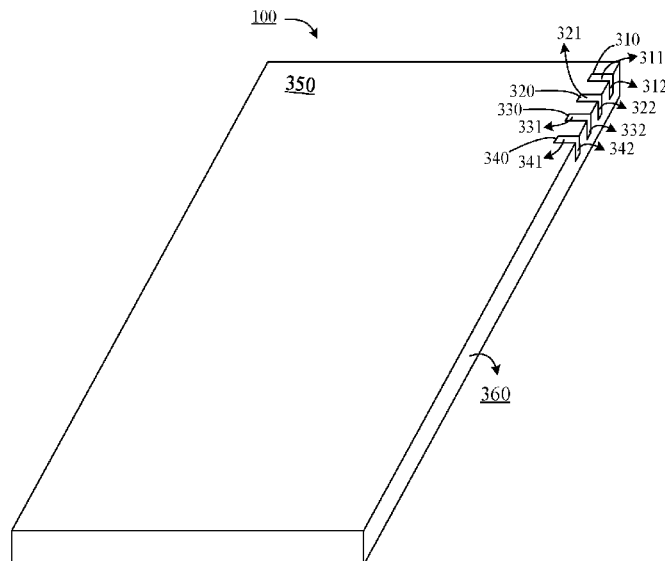
*Primary Examiner* — Tan H Trinh

(74) *Attorney, Agent, or Firm* — Syncoda LLC; Feng Ma

(57) **ABSTRACT**

A frame body of the metal middle frame includes a first side and a second side, which are jointed at a side edge of the first side and second side; an L-shaped slit is arranged on the frame body, and includes a first slit edge and a second slit edge which are jointed at an end point of the first slit edge and the second slit edge, the first slit edge is arranged on the first side, and the second slit edge is arranged on the second side; and a millimeter-wave antenna is arranged in the L-shaped slit, and the millimeter-wave antenna is configured to perform millimeter-wave radiation through the first slit edge and the second slit edge.

**20 Claims, 5 Drawing Sheets**



(12) **United States Patent**  
**Yao et al.**

(10) **Patent No.:** **US 11,271,303 B2**  
(45) **Date of Patent:** **Mar. 8, 2022**

(54) **ANTENNA, SMART WINDOW, AND METHOD OF FABRICATING ANTENNA**

(71) Applicant: **BOE Technology Group Co., Ltd.**, Beijing (CN)

(72) Inventors: **Yuan Yao**, Beijing (CN); **Lei Wang**, Beijing (CN); **Tuo Sun**, Beijing (CN)

(73) Assignees: **BOE Technology Group Co., Ltd.**, Beijing (CN); **Beijing University of Posts and Telecommunications**, Beijing (CN)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 36 days.

(21) Appl. No.: **16/756,111**

(22) PCT Filed: **May 24, 2019**

(86) PCT No.: **PCT/CN2019/088324**

§ 371 (c)(1),

(2) Date: **Apr. 14, 2020**

(87) PCT Pub. No.: **WO2020/140368**

PCT Pub. Date: **Jul. 9, 2020**

(65) **Prior Publication Data**

US 2021/0226325 A1 Jul. 22, 2021

(30) **Foreign Application Priority Data**

Jan. 3, 2019 (CN) ..... 201910004275.5

Jan. 3, 2019 (CN) ..... 201910004663.3

(51) **Int. Cl.**

**H01Q 1/38** (2006.01)

**H01Q 5/35** (2015.01)

(Continued)

(52) **U.S. Cl.**

CPC ..... **H01Q 5/35** (2015.01); **H01Q 1/36** (2013.01); **H01Q 1/38** (2013.01); **H01Q 21/26** (2013.01)

(58) **Field of Classification Search**

CPC .. **H01Q 1/36**; **H01Q 1/38**; **H01Q 5/25**; **H01Q 5/35**; **H01Q 9/065**; **H01Q 9/28**  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,428,364 A 6/1995 Lee et al.  
6,346,913 B1 \* 2/2002 Chang ..... **H01Q 9/0407**  
343/700 MS

(Continued)

FOREIGN PATENT DOCUMENTS

CN 1833474 A 9/2006  
CN 201048157 Y 4/2008

(Continued)

OTHER PUBLICATIONS

International Search Report & Written Opinion dated Sep. 27, 2019, regarding PCT/CN2019/088324.

(Continued)

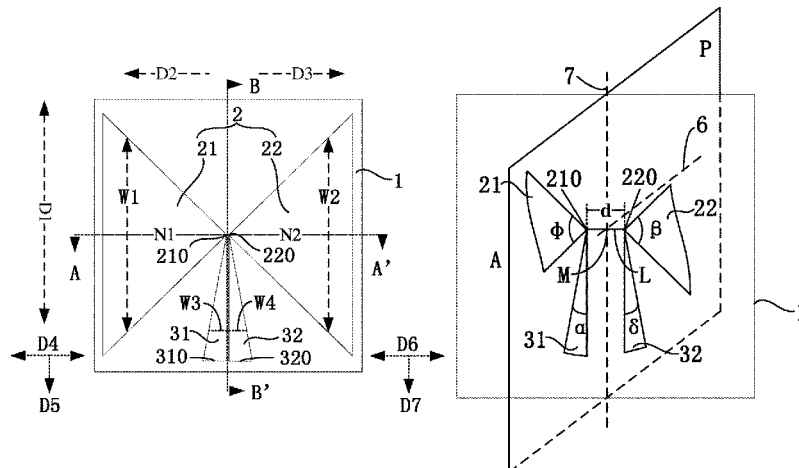
*Primary Examiner* — Thien M Le

(74) *Attorney, Agent, or Firm* — Intellectual Valley Law, P.C.

(57) **ABSTRACT**

An antenna is provided. The antenna includes a substantially transparent base substrate; a first pattern having a first feed point and a second pattern having a second feed point spaced apart from each other; a first feed line electrically connected to the first pattern through the first feed point; and a second feed line electrically connected to the second pattern through the second feed point. A first width along a first direction, of the first pattern, gradually increases along a second direction. A second width along the first direction, of the second pattern, gradually increases along a third direction substan-

(Continued)



(12) **United States Patent**  
**Kakuya et al.**

(10) **Patent No.:** **US 11,271,310 B2**  
(45) **Date of Patent:** **Mar. 8, 2022**

(54) **ANTENNA DEVICE**  
(71) Applicant: **DENSO CORPORATION**, Kariya (JP)  
(72) Inventors: **Yuuji Kakuya**, Nisshin (JP); **Hidenori Akita**, Kariya (JP); **Masakazu Ikeda**, Nisshin (JP); **Kenichirou Sanji**, Nisshin (JP); **Hiroyuki Izumi**, Kariya (JP)  
(73) Assignee: **DENSO CORPORATION**, Kariya (JP)  
(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

2010/0283705 A1 11/2010 Achour et al.  
2012/0268347 A1\* 10/2012 Tatarnikov ..... H01Q 9/0407  
343/893  
2013/0002377 A1 1/2013 Toyao et al.  
2014/0097990 A1\* 4/2014 Aboush ..... H01Q 21/065  
343/700 MS

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2014-003670 A 1/2014  
JP 2015-142367 A 8/2015

(Continued)

OTHER PUBLICATIONS

(21) Appl. No.: **16/840,484**  
(22) Filed: **Apr. 6, 2020**  
(65) **Prior Publication Data**  
US 2020/0328516 A1 Oct. 15, 2020

Terada et al., "Dual-Band Zeroth-Order Resonant Antenna", Proceedings of the 2017 IEICE Society Conference vol. 1, The Institute of Electronics, Information and Communication Engineers p. 68, Aug. 2017.

*Primary Examiner* — Crystal L Hammond  
(74) *Attorney, Agent, or Firm* — Hamess, Dickey & Pierce, P.L.C.

(30) **Foreign Application Priority Data**  
Apr. 10, 2019 (JP) ..... JP2019-075085

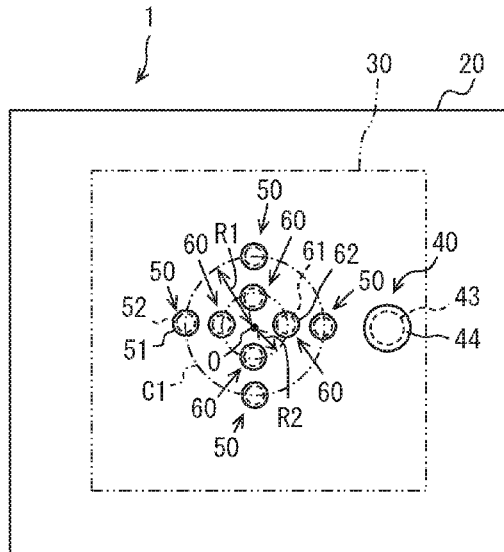
(57) **ABSTRACT**

(51) **Int. Cl.**  
**H01Q 9/04** (2006.01)  
**H01Q 1/48** (2006.01)  
(52) **U.S. Cl.**  
CPC ..... **H01Q 9/0407** (2013.01); **H01Q 1/48** (2013.01)  
(58) **Field of Classification Search**  
None  
See application file for complete search history.

An antenna device includes a ground plate that is a conductive member having a plate shape, a patch section that is a conductive member having a plate shape and is disposed in parallel with the ground plate with a predetermined interval so as to face the ground plate, a plurality of first short-circuit vias each having an axial center disposed on a circumference of a via arrangement circle located in a center portion of the patch section and each having a first end connected with the patch section and a second end connected with the ground plate, and at least one second short-circuit via having an axial center disposed at a position different from the circumference of the via arrangement circle and having a first end connected with the patch section and a second end connected with the ground plate.

(56) **References Cited**  
U.S. PATENT DOCUMENTS  
2008/0258981 A1 10/2008 Achour et al.  
2010/0283692 A1 11/2010 Achour et al.

**3 Claims, 5 Drawing Sheets**





(12) **United States Patent**  
**Chiu et al.**

(10) **Patent No.:** **US 11,271,311 B2**  
(45) **Date of Patent:** **\*Mar. 8, 2022**

(54) **COMPACT WIDEBAND INTEGRATED THREE-BROADSIDE-MODE PATCH ANTENNA**

(71) Applicant: **The Hong Kong University of Science and Technology**, Hong Kong (CN)

(72) Inventors: **Chi Yuk Chiu**, Hong Kong (CN); **Ross David Murch**, Hong Kong (CN)

(73) Assignee: **THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY**, Hong Kong (CN)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.  
  
This patent is subject to a terminal disclaimer.

(21) Appl. No.: **17/064,266**

(22) Filed: **Oct. 6, 2020**

(65) **Prior Publication Data**  
US 2021/0021041 A1 Jan. 21, 2021

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 16/220,916, filed on Dec. 14, 2018, now Pat. No. 10,854,977.

(60) Provisional application No. 62/973,720, filed on Oct. 22, 2019, provisional application No. 62/708,755, filed on Dec. 21, 2017.

(51) **Int. Cl.**  
**H01Q 9/04** (2006.01)  
**H01Q 21/06** (2006.01)  
**H01Q 5/50** (2015.01)  
**H01Q 5/15** (2015.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 9/0407** (2013.01); **H01Q 5/15** (2015.01); **H01Q 5/50** (2015.01); **H01Q 21/065** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 9/0407; H01Q 5/15; H01Q 5/50; H01Q 21/065; H01Q 21/24; H01Q 21/28  
See application file for complete search history.

(56) **References Cited**  
  
U.S. PATENT DOCUMENTS  
  
4,410,891 A 10/1983 Schaubert et al.  
5,307,075 A 4/1994 Huynh  
5,880,694 A \* 3/1999 Wang ..... H01Q 5/378  
343/700 MS

(Continued)

**FOREIGN PATENT DOCUMENTS**

TW 201731162 A 9/2017

**OTHER PUBLICATIONS**

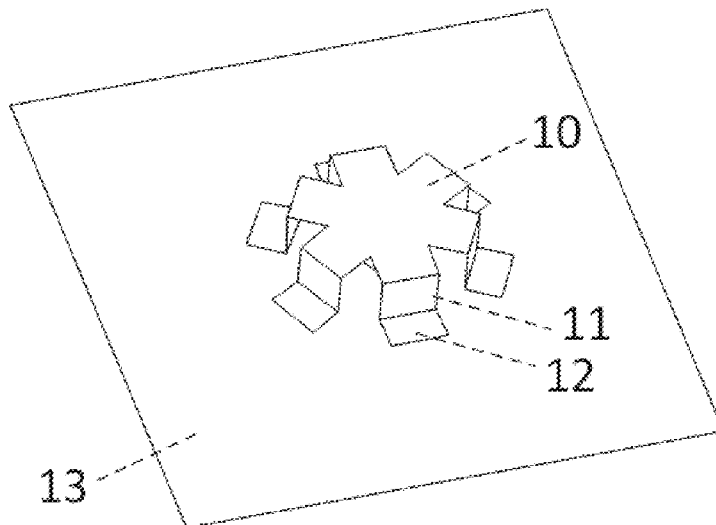
Ko et al., "Compact Integrated Diversity Antenna for Wireless Communications", *IEEE Transactions on Antennas and Propagation*, 49(6): 954-960 (2001).

(Continued)

*Primary Examiner* — Hoang V Nguyen  
(74) *Attorney, Agent, or Firm* — Leydig, Voit & Mayer, Ltd.

(57) **ABSTRACT**  
A three-broadside-mode patch antenna includes: a rotationally symmetric radiator; a patch, wherein the patch is separated from the rotationally symmetric radiator by a dielectric and configured to capacitively feed the rotationally symmetric radiator; and three antenna probes, connected to the patch, configured to provide three antenna ports corresponding to three respective broadside radiation polarizations.

**21 Claims, 27 Drawing Sheets**





US011271314B2

(12) **United States Patent**  
**Ishizuka**

(10) **Patent No.:** **US 11,271,314 B2**  
(45) **Date of Patent:** **Mar. 8, 2022**

(54) **ANTENNA COUPLING ELEMENT,  
ANTENNA DEVICE, AND ELECTRONIC  
DEVICE**

(71) Applicant: **Murata Manufacturing Co., Ltd.,**  
Nagaokakyo (JP)

(72) Inventor: **Kenichi Ishizuka,** Nagaokakyo (JP)

(73) Assignee: **MURATA MANUFACTURING CO.,  
LTD.,** Kyoto (JP)

(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 10 days.

(21) Appl. No.: **16/744,226**

(22) Filed: **Jan. 16, 2020**

(65) **Prior Publication Data**

US 2020/0153099 A1 May 14, 2020

**Related U.S. Application Data**

(63) Continuation of application No.  
PCT/JP2018/021580, filed on Jun. 5, 2018.

(30) **Foreign Application Priority Data**

Jul. 21, 2017 (JP) ..... JP2017-141549

(51) **Int. Cl.**

**H01Q 5/30** (2015.01)

**H01Q 9/04** (2006.01)

**H01Q 1/48** (2006.01)

(52) **U.S. Cl.**

CPC ..... **H01Q 9/045** (2013.01); **H01Q 1/48**  
(2013.01)

(58) **Field of Classification Search**

CPC ..... H01Q 1/48-1/50; H01Q 5/30-5/392  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0309994 A1*	12/2011	Kato	.....	H01Q 1/50	343/860
2014/0049440 A1	2/2014	Ueki et al.			
2014/0218246 A1	8/2014	Ishizuka et al.			
2014/0266964 A1*	9/2014	Kato	.....	H01Q 1/50	343/860
2017/0194692 A1	7/2017	Sayama et al.			
2021/0119335 A1*	4/2021	Mizuno	.....	H01Q 5/307	

FOREIGN PATENT DOCUMENTS

JP	2014-053808 A	3/2014
WO	2012/153690 A1	11/2012
WO	2014/034587 A1	3/2014
WO	2015/182340 A1	12/2015
WO	2016/052733 A1	4/2016

OTHER PUBLICATIONS

Official Communication issued in International Patent Application  
No. PCT/JP2018/021580, dated Aug. 28, 2018.

\* cited by examiner

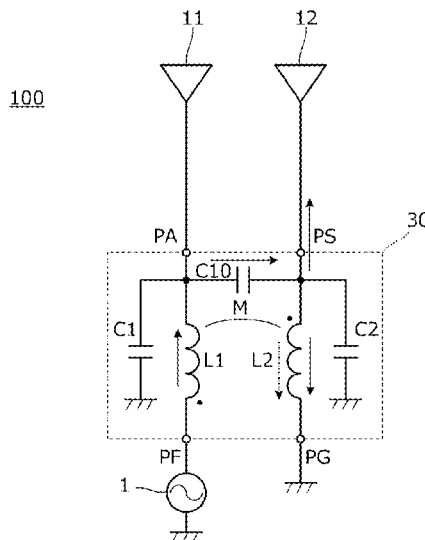
*Primary Examiner* — Hasan Islam

(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

An antenna device includes first and second radiating elements, and an antenna coupling element. The antenna coupling element includes a primary coil electrically connected between the first radiating element and a feed circuit and a secondary coil inductively coupled to the primary coil and electrically connected between the second radiating element and a ground. A capacitor is provided between the primary coil and the secondary coil, thus causing current to flow from the primary coil to the secondary coil or the second radiating element via the capacitor even at an anti-resonant frequency of the first radiating element.

**17 Claims, 6 Drawing Sheets**





(12) **United States Patent**  
**Onaka et al.**

(10) **Patent No.:** **US 11,271,315 B2**  
(45) **Date of Patent:** **Mar. 8, 2022**

(54) **ANTENNA MODULE AND COMMUNICATION DEVICE**

- (71) Applicant: **Murata Manufacturing Co., Ltd.**,  
Kyoto (JP)
- (72) Inventors: **Kengo Onaka**, Kyoto (JP); **Yoshiki Yamada**, Kyoto (JP); **Keiichi Hirose**,  
Kyoto (JP); **Hirotsugu Mori**, Kyoto  
(JP)
- (73) Assignee: **MURATA MANUFACTURING CO., LTD.**, Kyoto (JP)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 57 days.

(21) Appl. No.: **16/818,339**

(22) Filed: **Mar. 13, 2020**

(65) **Prior Publication Data**  
US 2020/0220270 A1 Jul. 9, 2020

**Related U.S. Application Data**  
(63) Continuation of application No. PCT/JP2018/028180, filed on Jul. 27, 2018.

(30) **Foreign Application Priority Data**  
Sep. 14, 2017 (JP) ..... JP2017-176596

(51) **Int. Cl.**  
**H01Q 1/38** (2006.01)  
**H01Q 9/04** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **H01Q 9/045** (2013.01); **H01Q 1/2208** (2013.01); **H01Q 1/422** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 9/045; H01Q 1/2208; H01Q 1/422; H01Q 1/241  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

- 6,147,648 A 11/2000 Granholm et al.
- 2003/0214368 A1\* 11/2003 Taniguchi ..... H03H 9/725 333/133

(Continued)

FOREIGN PATENT DOCUMENTS

- CN 103179779 A 6/2013
- JP 2000-508144 A 6/2000

(Continued)

OTHER PUBLICATIONS

International Search Report issued in Patent Application No. PCT/JP2018/028180 dated Oct. 16, 2018.

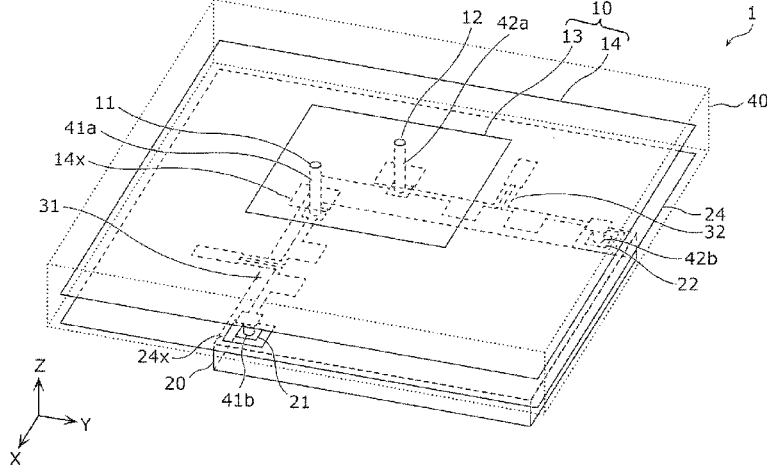
(Continued)

*Primary Examiner* — Dieu Hien T Duong  
(74) *Attorney, Agent, or Firm* — Pearne & Gordon LLP

(57) **ABSTRACT**

An antenna module includes a multilayer substrate having a first main surface and a second main surface opposing to each other, a patch antenna formed on a side of the first main surface of the multilayer substrate and configured with a radiation electrode and a ground electrode, an RFIC formed on a side of the second main surface of the multilayer substrate, a first filter, and a second filter different from the first filter, wherein the patch antenna has a first feed point and a second feed point provided at different positions in the radiation electrode, the first feed point is electrically connected to the RFIC via the first filter, the second feed point is electrically connected to the RFIC via the second filter, and the first filter and the second filter are formed in the multilayer substrate.

**20 Claims, 10 Drawing Sheets**





US011271322B2

(12) **United States Patent**  
**Chan et al.**

(10) **Patent No.:** **US 11,271,322 B2**  
(45) **Date of Patent:** **Mar. 8, 2022**

(54) **SUBSTRATE INTEGRATED WAVEGUIDE FED ANTENNA**

21/062; H01Q 5/378; H01Q 13/106;  
H01Q 19/108; H01Q 19/005; H01Q  
5/392; H01Q 21/0037; H01Q 9/16

(71) Applicant: **City University of Hong Kong,**  
Kowloon (HK)

See application file for complete search history.

(56) **References Cited**

(72) Inventors: **Chi Hou Chan,** Kowloon (HK);  
**Manting Wang,** Kowloon (HK)

U.S. PATENT DOCUMENTS

(73) Assignee: **City University of Hong Kong,**  
Kowloon (HK)

4,710,775 A \* 12/1987 Coe ..... H01Q 13/18  
343/727  
7,843,389 B2 11/2010 Luk et al.  
7,999,744 B2 8/2011 Chin et al.  
9,431,712 B2 8/2016 Abadi et al.  
10,090,584 B2 10/2018 Duan et al.  
10,211,535 B2 2/2019 Rahmat-Samii et al.

(\* ) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 0 days.

(Continued)

(21) Appl. No.: **16/889,089**

OTHER PUBLICATIONS

(22) Filed: **Jun. 1, 2020**

IEEE Transactions on Antennas and Propagation, vol. 65, No. 12,  
Dec. 2017 Substrate-Integrated-Waveguide-Fed Array Antenna Cov-  
ering 57-71 GHz Band for 5G Applications—Zhu et al. (Year:  
2017).\*

(65) **Prior Publication Data**

US 2021/0376483 A1 Dec. 2, 2021

(Continued)

(51) **Int. Cl.**

**H01Q 21/00** (2006.01)  
**H01Q 9/06** (2006.01)  
**H01Q 5/30** (2015.01)  
**H01Q 21/06** (2006.01)  
**H01Q 9/16** (2006.01)  
**H01Q 9/28** (2006.01)  
**H01Q 5/378** (2015.01)  
**H01Q 5/392** (2015.01)

Primary Examiner — Vibol Tan

(74) *Attorney, Agent, or Firm* — Renner Kenner Greive  
Bobak Taylor & Weber

(52) **U.S. Cl.**

CPC ..... **H01Q 21/0037** (2013.01); **H01Q 5/378**  
(2015.01); **H01Q 5/392** (2015.01); **H01Q**  
**9/065** (2013.01); **H01Q 9/16** (2013.01); **H01Q**  
**9/285** (2013.01); **H01Q 21/062** (2013.01)

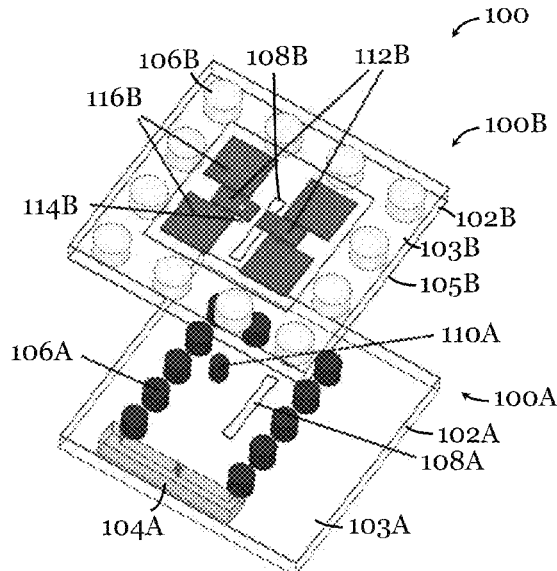
(57) **ABSTRACT**

A substrate integrated waveguide fed antenna. The antenna  
includes an electric dipole, a parasitic patch arrangement  
operably coupled with the electric dipole, and a feed struc-  
ture. The feed structure includes a substrate integrated  
waveguide operably coupled with the electric dipole for  
exciting the electric dipole. A slotted conductive surface  
with a slot is arranged between the electric dipole and the  
feed structure for operably coupling the feed structure with  
the electric dipole.

(58) **Field of Classification Search**

CPC ..... H01Q 9/285; H01Q 21/065; H01Q 9/065;  
H01Q 13/10; H01Q 21/0075; H01Q

**33 Claims, 25 Drawing Sheets**  
**(2 of 25 Drawing Sheet(s) Filed in Color)**







(12) **United States Patent**  
**Fang et al.**

(10) **Patent No.:** **US 11,271,326 B2**  
(45) **Date of Patent:** **Mar. 8, 2022**

(54) **ANTENNA SYSTEM**

(56) **References Cited**

(71) Applicant: **Wistron Corp.**, New Taipei (TW)

U.S. PATENT DOCUMENTS

(72) Inventors: **Ying-Sheng Fang**, New Taipei (TW);  
**Po-Tsang Lin**, New Taipei (TW);  
**Chia-Wei Su**, New Taipei (TW);  
**Pei-Cheng Hu**, New Taipei (TW)

7,675,466	B2 *	3/2010	Gaucher	.....	H01Q 21/0006	343/700 MS
10,297,916	B2 *	5/2019	Ku	.....	H01Q 21/08	
2003/0034920	A1 *	2/2003	Lee	.....	H01Q 21/065	343/700 MS
2007/0126641	A1 *	6/2007	Saily	.....	H01Q 9/0457	343/700 MS
2007/0229359	A1 *	10/2007	Heyde	.....	H01Q 9/0442	343/700 MS

(73) Assignee: **WISTRON CORP.**, New Taipei (TW)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 30 days.

(Continued)

(21) Appl. No.: **16/281,336**

Machine Translation of Publication: JP2000059136 A, Feb. 25, 2000 (Year: 2000).\*

(22) Filed: **Feb. 21, 2019**

(Continued)

(65) **Prior Publication Data**  
US 2020/0235491 A1 Jul. 23, 2020

*Primary Examiner* — Amy Cohen Johnson  
*Assistant Examiner* — James H Cho

(74) *Attorney, Agent, or Firm* — McClure, Qualey & Rodack, LLP

(30) **Foreign Application Priority Data**

Jan. 22, 2019 (TW) ..... 108102350

(57) **ABSTRACT**

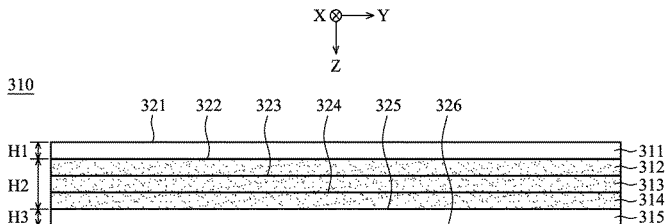
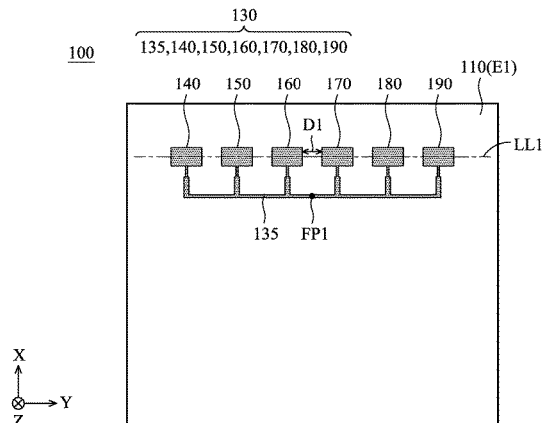
(51) **Int. Cl.**  
**H01Q 21/08** (2006.01)  
**H01Q 9/06** (2006.01)  
**H01Q 1/48** (2006.01)  
**H01Q 21/00** (2006.01)

An antenna system includes a dielectric substrate, a ground plane, and a first antenna array. The ground plane is disposed on a second surface of the dielectric substrate. The first antenna array is disposed on a first surface of the dielectric substrate. The first antenna array includes a first transmission line, a first antenna element, a second antenna element, a third antenna element, a fourth antenna element, a fifth antenna element, and a sixth antenna element. The first transmission line has a first feeding point and is coupled to the first antenna element, the second antenna element, the third antenna element, the fourth antenna element, the fifth antenna element, and the sixth antenna element. The first antenna element, the second antenna element, the third antenna element, the fourth antenna element, the fifth antenna element, and the sixth antenna element are all substantially arranged in a first straight line.

(52) **U.S. Cl.**  
CPC ..... **H01Q 21/08** (2013.01); **H01Q 1/48** (2013.01); **H01Q 9/06** (2013.01); **H01Q 21/0006** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 21/00; H01Q 21/06  
USPC ..... 343/848, 893  
See application file for complete search history.

**15 Claims, 8 Drawing Sheets**





US011276916B2

(12) **United States Patent**  
**Kim et al.**

(10) **Patent No.:** **US 11,276,916 B2**

(45) **Date of Patent:** **Mar. 15, 2022**

(54) **ELECTRONIC DEVICE COMPRISING ANTENNA MODULE**

(71) Applicant: **Samsung Electronics Co., Ltd.**, Suwon-si (KR)

(72) Inventors: **Dongyeon Kim**, Suwon-si (KR); **Ahmed Hussain**, Suwon-si (KR); **Seongjin Park**, Suwon-si (KR); **Sehyun Park**, Suwon-si (KR); **Sumin Yun**, Suwon-si (KR); **Woomin Jang**, Suwon-si (KR); **Myunghun Jeong**, Suwon-si (KR); **Jehun Jong**, Suwon-si (KR); **Jaehoon Jo**, Suwon-si (KR)

(73) Assignee: **Samsung Electronics Co., Ltd.**, Suwon-si (KR)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/750,541**

(22) Filed: **Jan. 23, 2020**

(65) **Prior Publication Data**  
US 2020/0243948 A1 Jul. 30, 2020

(30) **Foreign Application Priority Data**  
Jan. 25, 2019 (KR) ..... 10-2019-0009581

(51) **Int. Cl.**  
**H01Q 13/10** (2006.01)  
**H01Q 9/04** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/243** (2013.01); **H01Q 1/38** (2013.01); **H01Q 9/0407** (2013.01)

(58) **Field of Classification Search**  
None  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,224,313 B2 5/2007 McKinzie, III et al.  
7,342,469 B2 3/2008 Lee et al.

(Continued)

FOREIGN PATENT DOCUMENTS

KR 16-2006-0061056 A 6/2006  
WO 2018/125240 A1 7/2018

OTHER PUBLICATIONS

International Search Report with Written Opinion dated May 19, 2020; International Appl. No. PCT/KR2020/001216.

(Continued)

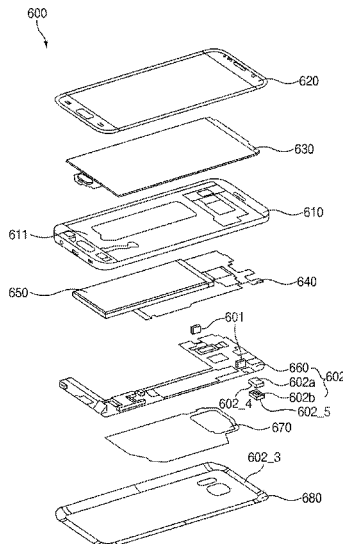
*Primary Examiner* — Pablo N Tran

(74) *Attorney, Agent, or Firm* — Jefferson IP Law, LLP

(57) **ABSTRACT**

An electronic device is provided. The electronic device includes a housing, a display exposed through at least part of the first plate, an antenna structure body disposed inside the housing and including a first surface facing the non-conductive portion and a second surface facing away from the first surface, a spacer structure coupled to the first surface or integrally formed with the antenna structure body to protrude from the first surface without overlapping with the conductive pattern when viewed from above the first surface, and a wireless communication circuit electrically connected to the conductive pattern and configured to transmit or receive a signal. At least part of the first plate, the second plate, or the side member includes a non-conductive portion. The antenna structure body includes at least one conductive pattern disposed between the first surface and the second surface or on the first surface.

**19 Claims, 12 Drawing Sheets**





US011276923B2

(12) **United States Patent**  
**Chen et al.**

(10) **Patent No.:** **US 11,276,923 B2**

(45) **Date of Patent:** **Mar. 15, 2022**

(54) **MULTI-BAND ANTENNA ARRANGEMENT**

(56) **References Cited**

(71) Applicant: **NOKIA SOLUTIONS AND NETWORKS OY**, Espoo (FI)

U.S. PATENT DOCUMENTS

(72) Inventors: **Jiangcheng Chen**, Oulu (FI); **Markus Berg**, Kiiminki (FI)

7,061,442 B1	6/2006	Tang et al.	
2014/0028529 A1	1/2014	Waidmann et al.	
2014/0062818 A1*	3/2014	Tsai	H01Q 5/335
			343/746
2019/0221940 A1*	7/2019	Pance	H01Q 19/18
		(Continued)	

(73) Assignee: **NOKIA SOLUTIONS AND NETWORKS OY**, Espoo (FI)

FOREIGN PATENT DOCUMENTS

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 127 days.

CN	1841846 A	10/2006
CN	203690491 U	7/2014
CN	203690501 U	7/2014
	(Continued)	

(21) Appl. No.: **16/863,634**

(22) Filed: **Apr. 30, 2020**

OTHER PUBLICATIONS

(65) **Prior Publication Data**

US 2020/0350672 A1 Nov. 5, 2020

Abde-Rahman et al., "Design of UWB Printed Monopole Antenna with Dual Band Notch Filter", IEEE Middle East Conference on Antennas and Propagation (MECAP 2010), (Oct. 20-22, 2010), 5 pages.

(30) **Foreign Application Priority Data**

(Continued)

May 2, 2019 (EP) ..... 19172157

Primary Examiner — Thanh C Le

(51) **Int. Cl.**

<b>H01Q 1/52</b>	(2006.01)
<b>H01Q 5/10</b>	(2015.01)
<b>H01Q 1/24</b>	(2006.01)
<b>H01Q 9/28</b>	(2006.01)

(74) *Attorney, Agent, or Firm* — Alston & Bird LLP

(52) **U.S. Cl.**

CPC ..... **H01Q 1/52** (2013.01); **H01Q 1/243** (2013.01); **H01Q 1/246** (2013.01); **H01Q 5/10** (2015.01); **H01Q 9/285** (2013.01)

(57) **ABSTRACT**

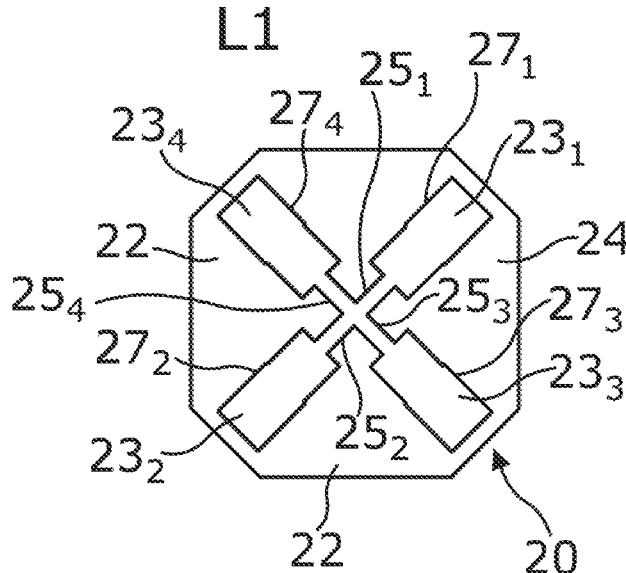
A multi-layer antenna arrangement is provided that includes a first layer having a conductive radiating element configured to have multiple overlapping resonant modes that define a first frequency range. The multi-layer antenna arrangement also includes a second layer having at least a portion of a ground plane for the conductive radiating element. The multi-layer antenna arrangement additionally includes a third layer, between the first layer and the second layer, that has a conductive resonator configured to provide a stop band within the first frequency range.

(58) **Field of Classification Search**

CPC ..... H01Q 1/38; H01Q 1/52; H01Q 1/243; H01Q 1/246; H01Q 5/345; H01Q 9/0442; H01Q 9/284; H01Q 5/10; H01Q 13/106

See application file for complete search history.

**16 Claims, 6 Drawing Sheets**



(12) **United States Patent**  
**Ramasamy**

(10) **Patent No.:** **US 11,276,925 B2**  
(45) **Date of Patent:** **Mar. 15, 2022**

(54) **SYSTEM AND METHOD FOR ESTABLISHING AND OPERATING PLURAL ANTENNA SYSTEMS IN PROXIMITY**

(71) Applicant: **Dell Products, LP**, Round Rock, TX (US)

(72) Inventor: **Suresh K. Ramasamy**, Austin, TX (US)

(73) Assignee: **Dell Products, LP**, Round Rock, TX (US)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/884,644**

(22) Filed: **Jan. 31, 2018**

(65) **Prior Publication Data**  
US 2019/0237865 A1 Aug. 1, 2019

(51) **Int. Cl.**  
**H01Q 1/52** (2006.01)  
**H01Q 5/35** (2015.01)  
**H01Q 1/22** (2006.01)  
**H01Q 21/00** (2006.01)  
**H01Q 1/02** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 1/523** (2013.01); **H01Q 1/02** (2013.01); **H01Q 1/2266** (2013.01); **H01Q 5/35** (2015.01); **H01Q 21/0025** (2013.01)

(58) **Field of Classification Search**  
CPC H01Q 1/523; H01Q 5/35; H01Q 1/02; H01Q 1/2266; H01Q 21/0025  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,760,749 A	6/1998	Minowa	
6,353,540 B1	3/2002	Akiba	
7,187,559 B2	3/2007	Hirabayashi	
9,887,165 B2	2/2018	Pagani	
2001/0040529 A1*	11/2001	Cheng	H01Q 1/241 343/702
2002/0036897 A1*	3/2002	Nakajima	G06F 1/1616 361/752
2002/0075186 A1	6/2002	Hamada	
2002/0135525 A1*	9/2002	Ikegaya	H01Q 9/0421 343/767
2003/0092396 A1*	5/2003	Fifield	H05K 1/0237 455/80

(Continued)

FOREIGN PATENT DOCUMENTS

CN 106935964 A 7/2017

*Primary Examiner* — Dimary S Lopez Cruz

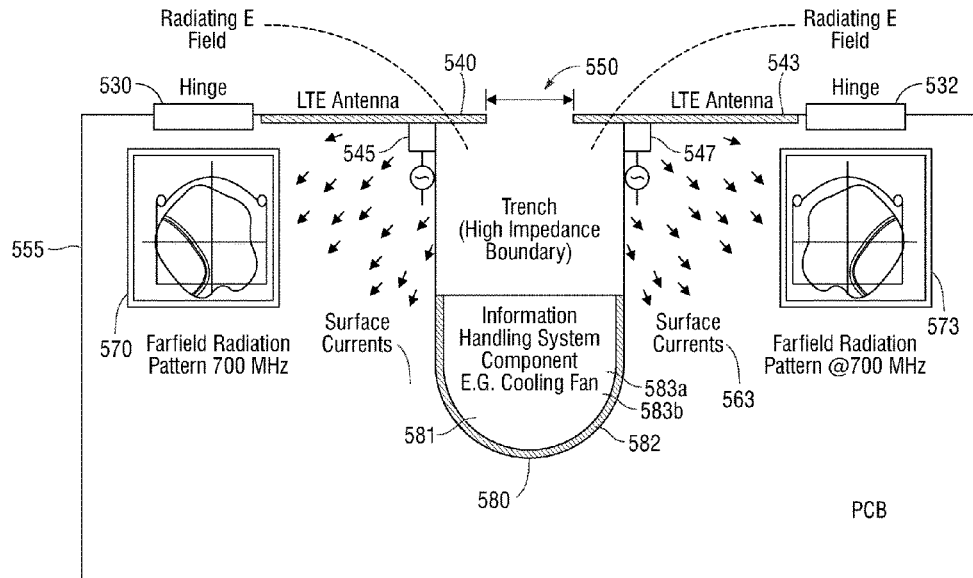
*Assistant Examiner* — Bamidele A Jegede

(74) *Attorney, Agent, or Firm* — Prol Intellectual Property Law, PLLC; H. Kenneth Prol

(57) **ABSTRACT**

An information handling system comprising a processor, a memory, and a wireless adapter with a first and second antenna feed operatively connected to the wireless adapter for communicating on a plurality of wireless links and disposed on a circuit board having a trench through one or more metallic layers with a perimeter edge dimension extending from an outer edge of the circuit board into the circuit board where the first antenna feed mounted adjacent to a first side of the trench of the circuit board and operatively connected to a first antenna and the second antenna feed mounted adjacent to a second side of the trench of the circuit board opposite to the first side and the second antenna feed operatively connected to a second antenna.

**20 Claims, 9 Drawing Sheets**





(12) **United States Patent**  
**Zhou et al.**

(10) **Patent No.:** **US 11,276,930 B2**  
(45) **Date of Patent:** **Mar. 15, 2022**

(54) **ANTENNA AND MOBILE TERMINAL**

(71) Applicant: **Huawei Technologies Co., Ltd.**,  
Shenzhen (CN)

(72) Inventors: **Dawei Zhou**, Beijing (CN); **Yuanpeng Li**, Beijing (CN); **Tiezhu Liang**, Beijing (CN); **Gonglei Zhang**, Beijing (CN)

(73) Assignee: **HUAWEI TECHNOLOGIES CO., LTD.**, Shenzhen (CN)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 88 days.

(21) Appl. No.: **16/620,359**

(22) PCT Filed: **Dec. 27, 2018**

(86) PCT No.: **PCT/CN2018/124150**

§ 371 (c)(1),

(2) Date: **Dec. 6, 2019**

(87) PCT Pub. No.: **WO2019/227914**

PCT Pub. Date: **Dec. 5, 2019**

(65) **Prior Publication Data**

US 2020/0106177 A1 Apr. 2, 2020

(30) **Foreign Application Priority Data**

Jun. 1, 2018 (CN) ..... 201810554555.9

(51) **Int. Cl.**

**H01Q 1/24** (2006.01)

**H01Q 1/48** (2006.01)

**H01Q 5/10** (2015.01)

(52) **U.S. Cl.**

CPC ..... **H01Q 5/10** (2015.01); **H01Q 1/24** (2013.01); **H01Q 1/48** (2013.01)

(58) **Field of Classification Search**

CPC .. **H01Q 5/10**; **H01Q 1/24**; **H01Q 1/48**; **H01Q 9/04**; **H01Q 5/335**; **H01Q 1/243**; **H01Q 5/364**; **H01Q 1/44**; **H01Q 5/378**  
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0284670 A1 11/2008 Kanno et al.  
2014/0078008 A1\* 3/2014 Kang ..... H01Q 1/38 343/702

(Continued)

FOREIGN PATENT DOCUMENTS

CN 203503779 U 3/2014  
CN 105449349 A 3/2016

(Continued)

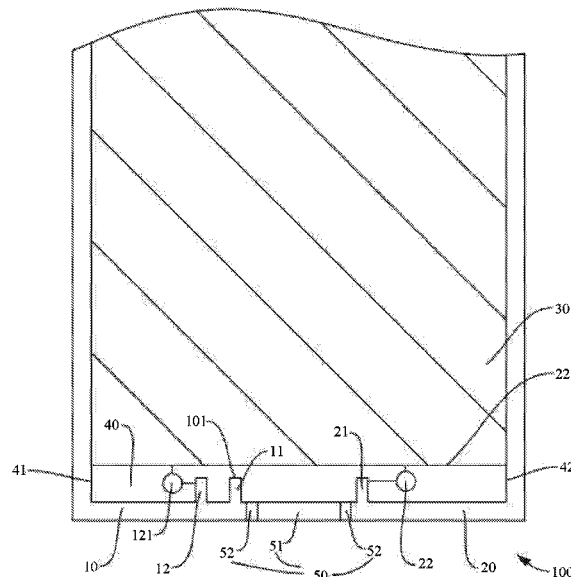
*Primary Examiner* — Hai V Tran

(74) *Attorney, Agent, or Firm* — Conley Rose, P.C.

(57) **ABSTRACT**

An antenna disposed on a mobile terminal, where the mobile terminal includes a radiation portion and a circuit board, the circuit board includes a lateral side and a grounding layer, and an insulating slot divides the radiation portion into a feed stub and a parasitic stub. A gap is encompassed by the circuit board and the radiation portion. There is a first branch that extends from the feed stub to the gap for feeding the antenna, and there is a second branch that extends from the parasitic stub to the gap and that is electrically connected to a grounding portion. The antenna excites a current loop winding around the gap on the grounding portion, the feed stub, and the parasitic stub.

**20 Claims, 13 Drawing Sheets**



(12) **United States Patent**  
**Leung et al.**

(10) **Patent No.:** **US 11,276,934 B2**  
(45) **Date of Patent:** **Mar. 15, 2022**

(54) **ANTENNA**

USPC ..... 343/731–737, 772–786, 825–831  
See application file for complete search history.

(71) Applicant: **City University of Hong Kong,**  
Kowloon (HK)

(56) **References Cited**

(72) Inventors: **Kwok Wa Leung,** Kowloon Tong  
(HK); **Lei Guo,** Kowloon Tong (HK);  
**Nan Yang,** Kowloon Tong (HK)

U.S. PATENT DOCUMENTS

(73) Assignee: **City University of Hong Kong,**  
Kowloon (HK)

3,710,340 A	1/1973	Mayes et al.	
3,868,694 A	2/1975	Meinke	
4,972,196 A	11/1990	Mayes et al.	
7,589,686 B2	9/2009	Balzovsky et al.	
7,843,389 B2	11/2010	Luk et al.	
2005/0017903 A1*	1/2005	Ittipiboon	..... H01Q 9/0485 343/700 MS
2010/0103061 A1	4/2010	Yung et al.	
2018/0115072 A1*	4/2018	Pance	..... H01Q 9/0485

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/002,261**

OTHER PUBLICATIONS

(22) Filed: **Jun. 7, 2018**

L. Guo, K. W. Leung, and Y. M. Pan, "Compact unidirectional ring dielectric resonator antennas with lateral radiation," IEEE Trans. Antennas Propag. , vol. 63 , No. 12, pp. 5334-5342, Dec. 2015.

(65) **Prior Publication Data**

US 2019/0379123 A1 Dec. 12, 2019

\* cited by examiner

(51) **Int. Cl.**

<b>H01Q 9/34</b>	(2006.01)
<b>H01Q 9/04</b>	(2006.01)
<b>H01Q 1/22</b>	(2006.01)
<b>H01Q 21/00</b>	(2006.01)
<b>H01Q 13/10</b>	(2006.01)
<b>H01Q 1/48</b>	(2006.01)

Primary Examiner — Binh B Tran

(74) *Attorney, Agent, or Firm* — Renner Kenner Greive  
Bobak Taylor & Weber

(52) **U.S. Cl.**

CPC ..... **H01Q 9/0485** (2013.01); **H01Q 1/22**  
(2013.01); **H01Q 1/48** (2013.01); **H01Q 13/10**  
(2013.01); **H01Q 21/0068** (2013.01)

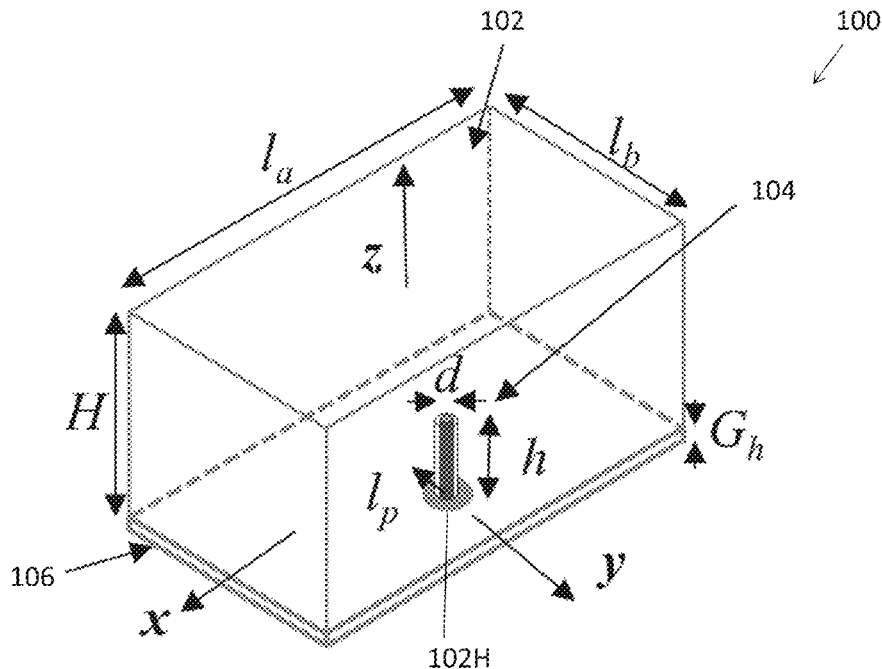
(57) **ABSTRACT**

An antenna and an antenna array, the antenna including a dielectric resonator fed by a feeder connected to a ground plane, wherein the dielectric resonator is arranged to emit an electromagnetic radiation along a wave propagation axis upon an electric excitation input to the feeder, and wherein the electromagnetic radiation is equivalent to a combination of a plurality of electromagnetic wave components.

(58) **Field of Classification Search**

CPC ..... H01Q 11/105; H01Q 13/02; H01Q 13/06;  
H01Q 13/04; H01Q 3/2664; H01Q 3/28;  
H01Q 13/24; H01Q 9/30; H01Q 9/38

**18 Claims, 11 Drawing Sheets**





US011276938B2

(12) **United States Patent**  
**Garrity et al.**

(10) **Patent No.:** **US 11,276,938 B2**

(45) **Date of Patent:** **Mar. 15, 2022**

(54) **SINGLE LAYER ANTENNA**

(71) Applicant: **Semtech Corporation**, Camarillo, CA (US)

(72) Inventors: **Paul James Garrity**, Rockwall, TX (US); **Ross Elliot Teggatz**, The Colony, TX (US); **Antony Eugene Brinlee**, Plano, TX (US)

(73) Assignee: **SEMTECH CORPORATION**, Camarillo, CA (US)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 220 days.

(21) Appl. No.: **16/229,120**

(22) Filed: **Dec. 21, 2018**

(65) **Prior Publication Data**

US 2019/0214735 A1 Jul. 11, 2019

**Related U.S. Application Data**

(60) Provisional application No. 62/616,323, filed on Jan. 11, 2018.

(51) **Int. Cl.**

**H01Q 1/48** (2006.01)

**H01Q 13/10** (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ..... **H01Q 13/10** (2013.01); **G06K 19/07786** (2013.01); **H01Q 1/2225** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC ..... H01Q 1/243; H01Q 1/38; H01Q 1/48; H01Q 13/106

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,404,395 B1 \* 6/2002 Masuda ..... H01Q 1/243  
343/700 MS

6,535,167 B2 3/2003 Masuda et al.  
(Continued)

FOREIGN PATENT DOCUMENTS

CN 107796294 3/2018  
CN 107919322 4/2018

(Continued)

OTHER PUBLICATIONS

Extended European Search Report for EP Application No. 19151276.3 dated May 31, 2019 by the European Patent Office, 9 pages.

(Continued)

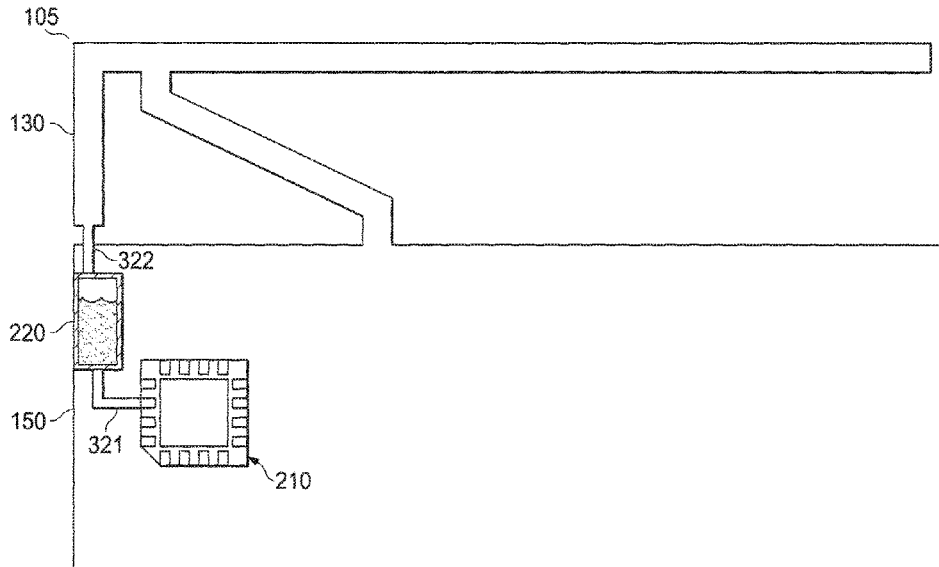
*Primary Examiner* — Hasan Islam

(74) *Attorney, Agent, or Firm* — Jackson Walker LLP; Christopher J. Rourke

(57) **ABSTRACT**

An antenna is disclosed that includes a ground plane extending in a first direction on a substrate and a radiating element occupying a same plane as the ground plane on the substrate, and coupled to the ground plane, the radiating element comprising a first portion with a first end and a second end extending in a substantially parallel direction to the ground plane, a feed line coupled to the first end of the first portion of the radiating element and extending in a substantially perpendicular direction from the first portion of the radiating element and a second portion having a third end and a fourth end, wherein the third end is coupled to the ground plane and the fourth end is coupled to the radiating element at a point between the first end and the second end.

**20 Claims, 4 Drawing Sheets**





US011276942B2

(12) **United States Patent**  
**Wong et al.**

(10) **Patent No.:** **US 11,276,942 B2**  
(45) **Date of Patent:** **Mar. 15, 2022**

(54) **HIGHLY-INTEGRATED MULTI-ANTENNA ARRAY**

FOREIGN PATENT DOCUMENTS

(71) Applicant: **INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE**, Hsinchu (TW)

CN 102456945 B 11/2014  
CN 102570058 B 11/2014

(Continued)

(72) Inventors: **Kin-Lu Wong**, Kaohsiung (TW); **Wei-Yu Li**, Yilan (TW); **Wei Chung**, Hengshan Township (TW)

OTHER PUBLICATIONS

(73) Assignee: **INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE**, Hsinchu (TW)

Abedin et al., "Effects of EBG Reflection Phase Profiles on the Input Impedance and Bandwidth of Ultrathin Directional Dipoles," IEEE Transactions on Antennas and Propagation, vol. 53, No. 11, Nov. 2005, pp. 3664-3672.

(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

Primary Examiner — Jason Crawford

(74) Attorney, Agent, or Firm — Birch, Stewart, Kolasch & Birch, LLP

(21) Appl. No.: **16/728,926**

(22) Filed: **Dec. 27, 2019**

(57) **ABSTRACT**

(65) **Prior Publication Data**

US 2021/0203080 A1 Jul. 1, 2021

(51) **Int. Cl.**  
**H01Q 21/06** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **H01Q 21/064** (2013.01)

(58) **Field of Classification Search**  
CPC ..... H01Q 21/0043; H01Q 21/005; H01Q 21/0062; H01Q 21/0064; H01Q 13/085; H01Q 13/10; H01Q 13/106; H01Q 19/13  
See application file for complete search history.

A highly-integrated multi-antenna array comprising a first conductor layer, a second conductor layer, a plurality of conjoined conducting structures, a plurality of slot antennas, and a conjoined slot structure is provided. The first conductor layer and the second conductor layer are spaced apart by a first interval, and are electrically connected by the conjoined conducting structures. Each slot antenna has a radiating slot structure and a signal coupling line, which partially overlap or cross each other. All radiating slot structures are formed at the second conductor layer. Each signal coupling line is spaced apart from the second conductor layer by a coupling interval and has a signal feeding point. Each slot antenna is excited to generate at least one resonant mode covering at least one identical first communication band. The conjoined slot structure is formed at the second conductor layer and connects with all radiating slot structures.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,460,899 A 7/1984 Schmidt et al.  
4,590,478 A \* 5/1986 Powers ..... H01Q 13/106  
343/700 MS

(Continued)

**12 Claims, 6 Drawing Sheets**

