(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 913 892 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
02.09.2015 Bulletin 2015/36

(51) Int Cl.:
H01Q 21/06 *(2006.01)* ***H01Q 9/04*** *(2006.01)*
H01Q 9/42 *(2006.01)*

(21) Application number: **14290052.1**

(22) Date of filing: **27.02.2014**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(71) Applicant: **ALCATEL LUCENT**
92100 Boulogne-Billancourt (FR)

(72) Inventor: **Gimersky, Martin**
Dublin 15 (IE)

(74) Representative: **Sarup, David Alexander**
Alcatel-Lucent Telecom Ltd
Intellectual Property Business Group
Christchurch Way
Greenwich
London SE10 0AG (GB)

Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) An antenna, a multiple antenna array and a method of radiating a radio-frequency signal

(57) An antenna (2) is provided comprising a patch (4) located above a ground plane (8), the patch comprising a plate (12) and four side walls (16), the plate being at least substantially rectangular so as to have four edges, a respective one of the side walls extending down from each of the edges.

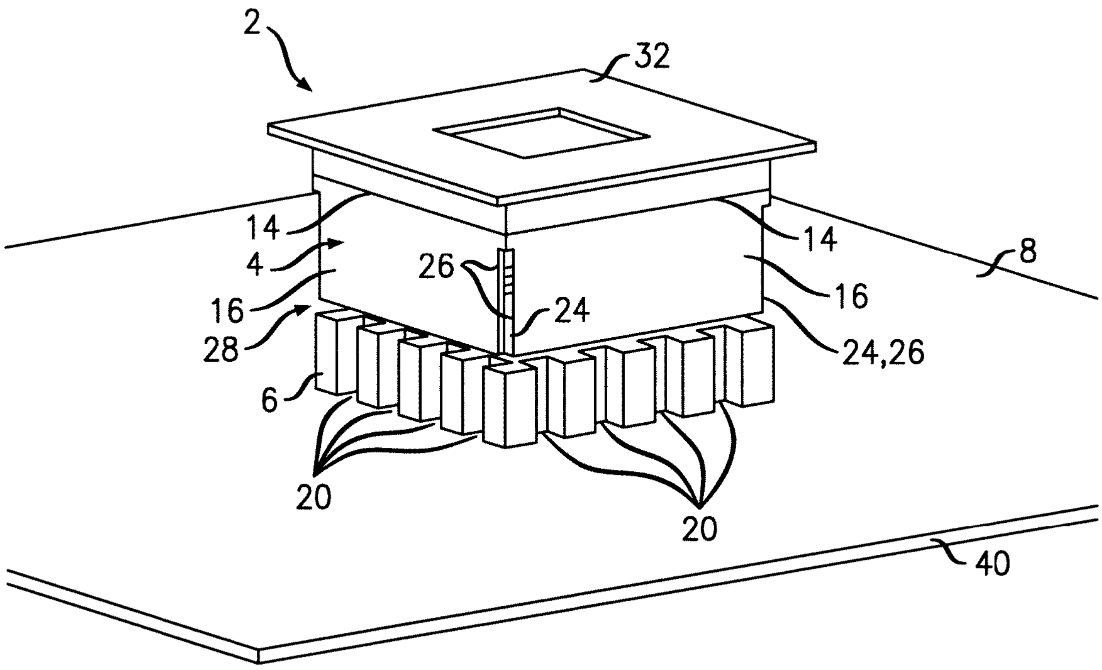

FIG. 1

EP 2 913 892 A1

Printed by Jouve, 75001 PARIS (FR)

Description

Field of the Invention

[0001] The present invention relates to antennas.

Description of the Related Art

[0002] Known antenna arrays use antennas which are often known as radiating antenna elements.

[0003] In large-scale antenna arrays, consisting of hundreds or thousands of radiating antenna elements, the theoretical limit for the gain, in dB, of an antenna array is given by G_{el} + 10*log N, where G_{el} is the gain, in dB, of the radiating element and *N* is the number of radiating elements. It follows from this that the larger the number of radiating elements, the less significant is the choice of radiating element.

[0004] In contrast, known antenna arrays for commercial wireless telecommunications, such as base station antennas, typically consist of a much smaller number of radiating elements, typically well below a hundred. Consequently the gain impact of a radiating element in these arrays is more significant. Furthermore, for multiband operation it may be necessary for each radiating element to have more than one radiator, where each radiator of a radiating element serves a different set of frequency bands.

[0005] In known base station antenna arrays, the physical spacing of radiating elements is typically between 0.5 and 1 wavelength. This is in order to adequately control grating lobes. Since the radiators are resonant, in other words approximately half a wavelength in size, this means that two or more radiators, placed together in a single composite radiating element, are in close proximity. (An example of such resonant radiators is a dipole fed via a split coaxial balun as described in T. A. Milligan. Modern Antenna Design - 2nd Edition. Hoboken, NJ: John Wiley & Sons, 2005, p. 255). This in turn, gives rise to non-negligible proximity-induced mutual electromagnetic coupling among the radiators of the composite radiating element. Mutual coupling is by its nature (being very frequency-dependent, very difficult to characterize analytically, etc.) an unwanted phenomenon, unaccounted for in established antenna array synthesis techniques. As a result, it is known that half-wavelength-size radiators are not best suited for interference-free incorporation in antenna arrays for mobile communication systems. It is known that electrically smaller radiators are needed instead.

[0006] A known radiating antenna element is an inverted U-shaped patch antenna as described in K.-L. Wong. Compact and Broadband Microstrip Antennas. New York, NY: John Wiley & Sons, 2002, pp. 1-7. This has a reduced antenna footprint as the two edge regions of the patch antenna, along the antenna's resonant or excitation direction, are in a bent-down configuration. The input signal is fed in at a location near one of the bent-down edges. The total length along the resonant path, in other words from one bent down edge of the patch antenna to the other, remains approximately a half wavelength, but the radiating edges of the patch antenna are closer together as a result of being in the bent down configuration. This patch antenna radiates linearly-polarised waves along the resonant path of the electric current flowing on the patch antenna surface.

[0007] A patch antenna is often simply referred to as a patch. A patch antenna is also known as a rectangular microstrip antenna.

[0008] As regards supporting a patch antenna in place, the known approach is the place the patch in a cupping support element which provides a backing cavity to the patch and within which the patch is supported. This cupping support element reduces the excitation of unwanted modes, reduces mutual coupling between adjacent radiating elements and/or serves as a heat-sink to improve heat dissipation, see for example the following three published papers:

J. A. Navarro et al. "A 29.3 GHz cavity-enclosed aperture-coupled circular patch antenna for microwave circuit integration". IEEE Microwave and Guided Wave Letters, vol. 1, no. 7, pp. 170-171, July 1991.

B. A. Brynjarsson and T. Syversen. "Cavity-enclosed, aperture coupled microstrip patch antenna," in IEE 1993 International Conference on Antennas and Propagation Symposium Proceedings, vol. 2, Edinburgh, UK, March-April 1993, pp. 715-718.

P. Ingvarson et al. "Patch-excited cup elements for satellite-based mobile communication antennas," in 2000 IEEE International Conference on Phrased Array Systems and Technology, Dana Point, CA, May 2000, pp. 215-218.

Summary

[0009] The reader is referred to the appended independent claims. Some preferred features are laid out in the dependent claims.

[0010] An example of the present invention is an antenna comprising a patch located above a ground plane, the patch comprising a plate and four side walls, the plate being at least substantially rectangular so as to have four edges, a respective one of the side walls extending down from each of the edges. In consequence the patch takes a smaller size than otherwise.

[0011] Preferably the plate is rectangular and has four edges or is substantially rectangular and the four edges are the four main edges. Preferably each side wall has at least substantially the same length as the corresponding edge from which the side wall extends.

[0012] Preferably a feeding signal input is coupled to the plate relatively near a corner formed by two of the walls that are near adjacent each other. This has the effect of allowing further reduced size of the antenna element.

[0013] Preferably there are two feeding signal inputs, one for each of two polarisations, each coupled to the plate relatively near a respective corner formed by two of the walls that are near adjacent each other.

[0014] Preferably the antenna radiates dual slant linear polarisations, one being +45° and one being -45°.

[0015] Preferably between at least one pair of the side walls that are near adjacent each other a respective slit is provided. Preferably between each two of the walls that are near adjacent each other a respective slit is provided. These slits aid antenna size reduction and provide an increased impedance bandwidth (relative to otherwise).

[0016] Preferably the patch is mounted above the ground plane on a pedestal. The pedestal is for impedance matching. Preferably the pedestal comprises external corrugations running in a direction towards the patch. The corrugations aid size reduction of the antenna by allowing the pedestal to usefully be substantially of the same footprint size as the patch.

[0017] Preferably the pedestal has a central aperture through which the or each signal input connector is connected to the patch. Alternatively, preferably the pedestal has a central cavity which is open toward the patch. The aperture or cavity enhances the gain of the antenna.

[0018] Preferably a parasitic-patch is located above the patch.

[0019] Preferably a parasitic-patch is spaced apart from the patch by a spacer layer of dielectric material.

[0020] Preferably, there is a gap between the patch and ground plane which is an air gap or is formed by one or more dielectric spacers.

Preferably, there is a gap between the patch and pedestal which is an air gap or is formed by one or more dielectric spacers.

[0021] Preferred embodiments provide a compact wideband radiating antenna element with enhanced gain.

[0022] Preferred embodiments have all of a reduced size, suitability for wideband operation, an enhanced gain and dual-polarisation operation capability.

[0023] In preferred embodiments, the footprint of the radiating antenna element including the parasitic-patch is only 0.3 wavelengths by 0.3 wavelengths at the lowest frequency of operation.

[0024] In preferred embodiments, the radiating antenna element has a compact form factor; in other words is packed into a compact volume namely a rectangular block without substantial appendages or extremities, such as dipole arms, sticking out. This provides for mechanical robustness and facilitates integration of multiple radiating antenna elements into antenna array (not shown) with low electromagnetic interference, in other words, low mutual coupling among the radiating antenna elements.

[0025] In preferred embodiments, the antenna element has a wide operating bandwidth; in one example a relative operating bandwidth of 24% is provided.

[0026] In preferred embodiments, the antenna element has an enhanced gain. Although the footprint of a preferred radiating antenna element is only 0.3 wavelengths by 0.3 wavelengths at the lowest frequency of operation, the preferred element has a gain corresponding to a known antenna element of 0.5 wavelengths by 0.5 wavelengths at the lowest frequency of operation, namely a pair of crossed half-wavelength dipoles fed by a split coaxial balun.

[0027] In preferred embodiments, only one feed point per polarisation is needed. This simplifies the signal distribution network, which is especially useful when multiple elements are used in an antenna array, and provides more flexibility in creating good antenna array configurations.

[0028] In preferred embodiments, the input signals are fed in via microstrip line so no balun or other impedence transformer is required.

[0029] The present invention also relates to a corresponding multiple antenna array.

[0030] The present invention also relates to a corresponding method of radiating a radio-frequency signal comprising exciting an antenna comprising a patch located above a ground plane, the patch comprising a plate and four side walls, the plate being at least substantially rectangular so as to have four edges, a respective one of the side walls extending down from each of the edges.

Brief Description of the Drawings

[0031] An embodiment of the present invention will now be described by way of example and with reference to the drawings, in which:

Figure 1 is an isometric perspective view of a radiating antenna element according to a first embodiment of the invention

Figure 2 is an exploded isometric perspective view of the element shown in Figure 1,

Figure 3 is a further exploded isometric perspective view of the element shown in Figures 1 and 2,

Figure 4 is a graphical representation of scattering parameters as a function of radio frequency of the element shown in Figures 1 to 3,

Figure 5 is a graphical representation of the co-polarized far-field gain radiation pattern of the element shown in Figures 1 to 3 at a radio frequency of 1.935 GHz, and

Figure 6 is a graphical representation of the cross-polarized far-field gain radiation pattern of the element shown in Figures 1 to 3 at a radio frequency of 1.935 GHz.

Detailed Description

[0032] As shown in Figures 1 to 3, an antenna 2 (often referred to as a radiating antenna or radiating antenna element) is provided which consists of a patch 4, a metallic pedestal 6, a metallic ground plane 8 and two feeding probes 10.

[0033] The patch 4 consists of a central rectangular plate 12 having four edges 14 along each of which there is a respective bent-down metallic wall 16. Accordingly, the patch 4 may be considered as having the approximate configuration of an inverted lid-less box or an inverted cup of rectangular cross section.

[0034] The ground plane 8 is electrically connected to the pedestal 6.

[0035] The pedestal 6 has a central aperture 18 within which the two feeding probes 10 are substantially disposed so as to provide power to the patch 4. Furthermore the pedestal 6 has multiple longitudinal outside corrugations 20.

[0036] The patch 4 has slits 24 cut along the corner edges 26 formed by the bent-down walls 16. The two feeding probes are directly connected to the patch 4.

[0037] There is a gap 28 between the patch 4 and the pedestal 6. In this example, the gap is an air gap. In some otherwise similar embodiments the gap is instead formed by one or more dielectric spacers positioned between the patch 4 and pedestal 6.

[0038] There are two support posts 30 provided between the ground plane 8 and the patch 4 through the central aperture 18 of the pedestal 6 so as to provide additional mechanical support to the patch 4 over the pedestal 6. The support posts are metallic or dielectric.

[0039] Above the patch 4, a parasitic-patch 32 is mounted, in this example supported over the patch 4 by a dielectric spacer 34. The parasitic-patch 32 acts to enhance bandwidth by introducing multiple resonances. These multiple resonances occur due to the proximity-coupling of the main patch 4 (sometimes denoted the fed patch) to the parasitic-patch 32. In this example, the parasitic-patch 32 is of a square ring shape as the fed patch 4 produces signals having dual slant linear polarisation.

[0040] As shown in Figure 3, each of the feeding probes 10 is transitioned to a respective microstrip line 36 on the bottom surface 38 of a standard Radiofrequency/ Microwave substrate material 40, the top surface of which is the ground plane 8.

[0041] The two feeding probes 10 together provide dual slant linear polarisation, that is with a + 45 degree or - 45 degree slant.

[0042] As used here, the term "metallic" refers to parts having electrically conducting surfaces. These parts could be manufactured in a variety of ways, for example as solid or sheet materials, electrically conducting plastics or metalized plastics.

<u>Discussion of some features of the radiating antenna element</u>

[0043] Before showing some results of performance calculations, we now further consider some of the features of the radiating antenna element shown in Figures 1 to 3.

<u>Bent-Down Walls</u>

[0044] From considering the known inverted U-shaped patch, the inventors realised that could be adapted for dual linear-polarisation operation. They realised this could be done by bending down the remaining two edge portions of the patch as well, thereby creating the bent -down walls 16 on all four sides in a configuration that may be considered an inverted cup having a rectangular base. The walls 16 are on a practical sense perpendicular to the plane in which the central rectangular plate 12 of the patch 4 lies. The footprint of the antenna element is thus reduced.

<u>Feeding probe near corner</u>

[0045] The two feeding probes 10 are each located at respective corners 42 formed by two of the walls 16 on adjacent edges 14, in other words near the slits 24 and the corner edges 26. This has the effect of reducing the footprint of the antenna element relative to having the feeding probes in a more central location, as the surface current is increased by a factor of $2^{1/2}$ so that for a given length of resonant path, in other words for a given resonant frequency, the footprint is reduced.

<u>Slits</u>

[0046] The slits 24 serve two purposes. Firstly, they have the effect of increasing the resonant path. In this example, the slits 24 lower the resonant frequency from 1.97 GHz to 1.84 GHz. In other words, the slits 24 reduce the patch 4 footprint for a resonance at a given frequency.

[0047] Secondly, the slits 24 have the effect of increasing the impedance bandwidth of the example patch 4 described above (relative to otherwise). In this example, the slits reduce the return loss of the radiating element 2 from 31.1 dB to 20.8 dB. This happens as the slits 24 mean that the electromagnetic energy contained in a cavity formed by the patch 4, pedestal 6 and ground plane 8 is less confined, lowering the quality factor (Q-factor) of the cavity.

[0048] It will be understood that, in design, the impedance bandwidth would increases if the width of the slits 24 were increased.

<u>Pedestal</u>

[0049] The pedestal 6 improves the impedance match of the patch 4. The pedestal 6 is hollow in having the central aperture 18. This central aperture 18 lies underneath the patch so that the cavity formed by the patch 4 pedestal 6 and ground plane 8 is basically not open to free space. The purpose of this cavity is to provide a higher gain.

Corrugations

[0050] As previously mentioned, the pedestal 6 has multiple longitudinal outside corrugations 20. These allow the area taken by the pedestal to be substantially the same size as the patch 4, thus acting to minimise the footprint of the radiating antenna element 2.

Feeding Probes

[0051] In this example, the feeding probes 10 are vertical and directly connected to the patch 4. There is a feeding probe 10 for each of the two polarisations. In consequence, there is good polarisation purity, in other words a low level of cross polarisation.

[0052] This is advantageous over known patch antennas (not shown) in which an additional feed (of equal magnitude and 180° phase shift) per polarisation in order to counteract the effects brought about by the excitation of higher order modes that cause polarisation impurity at the antenna.

Radiation Properties

[0053] Some simulations were made of scattering patterns and far-field gain radiation patterns of the radiating element shown in Figures 1 to 3.

[0054] The simulations were done using a full-wave software analysis tool known as CST Studio Suite 2013 from CST AG having a web address of www.cst.com/Content/Products/CST S2/Overview.aspx. Ohmic losses were included, and the mettalica parts were considered to be of copper.

[0055] Figure 4 shows scattering parameters as a function of radio frequency of the element. The solid line 44 represents the magnitude of the input reflection coefficient ($|S_{11|}$) as a function of frequency. The dashed line 46 represents magnitude of the forward transmission coefficient ($|S_{21}|$) as a function of frequency. The vertical dotted lines at frequency f_1 and frequency f_2 delimit the design operating frequency band bearing in mind that this example element is designed to have an operating frequency band of 1.70 to 2.17 GHz which corresponds to a relative bandwidth of 24.3%.

[0056] As shown in Figure 4, the local minimum in $|S_{11}|$ around 1.80 GHz is due to the resonance of the main patch 4 and the local minimum around 2.17 GHz is due to the resonance of the parasitic-patch 32.

Co-polarized far-field gain radiation pattern:

[0057] Figure 5 shows the co-polarized far-field gain radiation pattern of the element at a radio frequency of 1.935 GHz. The solid line 48 represents the gain in the E-plane cut; the dashed line 50 represents gain in the mid-plane cut; and the dash-dotted line 52 represents gain in the H-plane cut. Good co-polarised beam integrity is observed throught the designed operating frequency band.

Cross-polarized far-field gain radiation pattern:

[0058] Figure 6 is a graphical representation of the cross-polarized far-field gain radiation pattern of the element shown in Figures 1 to 3 at a radio frequency of 1.935 GHz. The solid line 54 represents the gain in the E-plane cut; the dashed line 56represents gain in the mid-plane cut; and the dash-dotted line 58 represents gain in the H-plane cut.

[0059] In both Figures 5 and 6, good polarisation purity is observed throughout the designed operating frequency band.

Possible Uses

[0060] These simulation results show the element 2 to be suitable both for use in antenna arrays and as a standalone antenna. The element 2 is suitable for use in multiband metrocell base stations and in macrocell active antenna arrays.

[0061] The use of dual-polarisation has benefits but there are practical limits on the achievable impedance match and port-to-port isolation. At a given performance level, there is a trade-off between impedance matching and port-to-port isolation. This is a consequence of the compact nature of the radiating element 2 causing proximity-coupling of electromagnetic energy between the two feeding probes 10. If further improvement in impedance-matching is desired, lumped elements can be used. For example, in some otherwise similar embodiments (not shown), inductors, capacitors and/or resistors (not shown) can be mounted between the microstrip line 36 and the ground plane 8 shown in Figure 3.

[0062] When the radiating element is used for only one polarisation, the achievable impedance match is, for practical engineering purposes, not related to the achievable port-to-port isolation.

Some Variants

[0063] Considering the example shown in Figures 1 to 3, in some alternative embodiments (not shown), the support posts are not provided as not required.

[0064] In some other embodiments (not shown) the pedestal has a cavity in its top surface, in other words in its surface nearest the patch, instead of the central aperture. This cavity does not go right through the pedestal instead of a central aperture which would go right through the pedestal.

[0065] In other embodiments (not shown) instead of two feeding probes, there are one or more feeding probes.

[0066] In some other embodiments (not shown), the patch has no slits between the acting to separate the bent down walls.

[0067] In some other embodiments (not shown) the feeding probes are proximity-coupled to the patch rather than being directly connected.

[0068] In some other embodiments the multiple longitudinal outside corrugations on the pedestal are absent.

[0069] The present invention may be embodied in other specific forms without departing from its essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

Claims

1. An antenna comprising a patch located above a ground plane, the patch comprising a plate and four side walls, the plate being at least substantially rectangular so as to have four edges, a respective one of the side walls extending down from each of the edges.

2. An antenna according to claim 1, in which each side wall has at least substantially the same length as the corresponding edge from which the side wall extends.

3. An antenna according to claim 1 or claim 2, in which there is at least one feeding signal input coupled to the patch.

4. An antenna according to claim 3, in which at least one of the feeding signal inputs is coupled to the central plate relatively near a respective corner formed by two of the walls that are near adjacent each other.

5. An antenna according to claim 4, in which there are two feeding signal inputs, one for each of two polarisations, each coupled to the plate relatively near a respective corner formed by two of the walls that are near adjacent each other.

6. An antenna according to claim 5, in which the antenna radiates dual slant linear polarisations, one being +45° and one being -45°.

7. An antenna according to any preceding claim, in which between at least one pair of the side walls that are near adjacent each other a respective slit is provided.

8. An antenna according to any preceding claim, in which the rectangular patch is mounted above the ground plane on a pedestal.

9. An antenna according to claim 7, in which the pedestal comprises external corrugations running in a direction towards the patch.

10. An antenna according to claim 8 or claim 9, in which the pedestal has a central aperture through which the or each feeding signal input is connected to the patch.

11. An antenna according to claim 8 or claim 9, in which the pedestal has a central cavity which is open toward the patch.

12. An antenna according to any preceding claim, in which a parasitic-patch is located above the patch.

13. An antenna according to any preceding claim, in which a parasitic-patch is spaced apart from the patch by a spacer layer of dielectric material.

14. A multiple antenna array comprising a plurality of antennas according to claims 1 to 13.

15. A method of radiating a radio-frequency signal comprising exciting an antenna comprising a patch located above a ground plane, the patch comprising a plate and four side walls, the plate being at least substantially rectangular so as to have four edges, a respective one of the side walls extending down from each of the edges.

Amended claims in accordance with Rule 137(2) EPC.

1. An antenna (2) comprising a patch (14) located above a ground plane (8), the patch comprising a plate (12) and four side walls (16), the plate being at least substantially rectangular so as to have four edges (14), a respective one of the side walls extending down from each of the edges,
<u>characterised in that</u>
there are two feeding signal inputs(10), one for each of two polarisations, each coupled to the plate (12) relatively near a respective corner (42) formed by two of the walls (16) that are near adjacent each other;
the signals which the antenna radiates have linear polarisations, one being +45° slant and one being -45° slant; and
in which the patch is mounted above the ground plane on a pedestal (6) and the pedestal (6) has a central aperture (18) through which each feeding signal input (10) is connected to the patch (4).

2. An antenna according to claim 1, in which each side wall (16) has at least substantially the same length as the corresponding edge from which the side wall

extends.

3. An antenna according to claim 1 or claim 2, in which there is at least one feeding signal input (10) coupled to the patch (4).

4. An antenna according to claim 3, in which at least one of the feeding signal inputs (10) is coupled to the central plate (12) relatively near a respective corner formed by two of the walls that are near adjacent each other.

5. An antenna according to any preceding claim, in which between at least one pair of the side walls (16) that are near adjacent each other a respective slit (24) is provided.

6. An antenna according to any preceding claim, in which the pedestal comprises external corrugations (20) running in a direction towards the patch.

7. An antenna according to any preceding claim, in which the pedestal has a central cavity which is open toward the patch (4).

8. An antenna according to any preceding claim, in which a parasitic-patch (32) is located above the patch (4).

9. An antenna according to any preceding claim, in which a parasitic-patch is spaced apart from the patch by a spacer layer (34) of dielectric material.

10. A multiple antenna array comprising a plurality of antennas according to claims 1 to 9.

11. A method of radiating a radio-frequency signal comprising exciting an antenna (2) comprising a patch located above a ground plane, the patch (4) comprising a plate (12) and four side walls(16), the plate being at least substantially rectangular so as to have four edges (14), a respective one of the side walls extending down from each of the edges,

characterised in that

there are two feeding signal inputs(10), one for each of two polarisations, each coupled to the plate (12) relatively near a respective corner (42) formed by two of the walls (16) that are near adjacent each other;

the signals which the antenna radiates have linear polarisations, one being +45° slant and one being -45° slant; and

in which the patch is mounted above the ground plane on a pedestal (6) and the pedestal (6) has a central aperture (18) through which each feeding signal input (10) is connected to the patch (4).

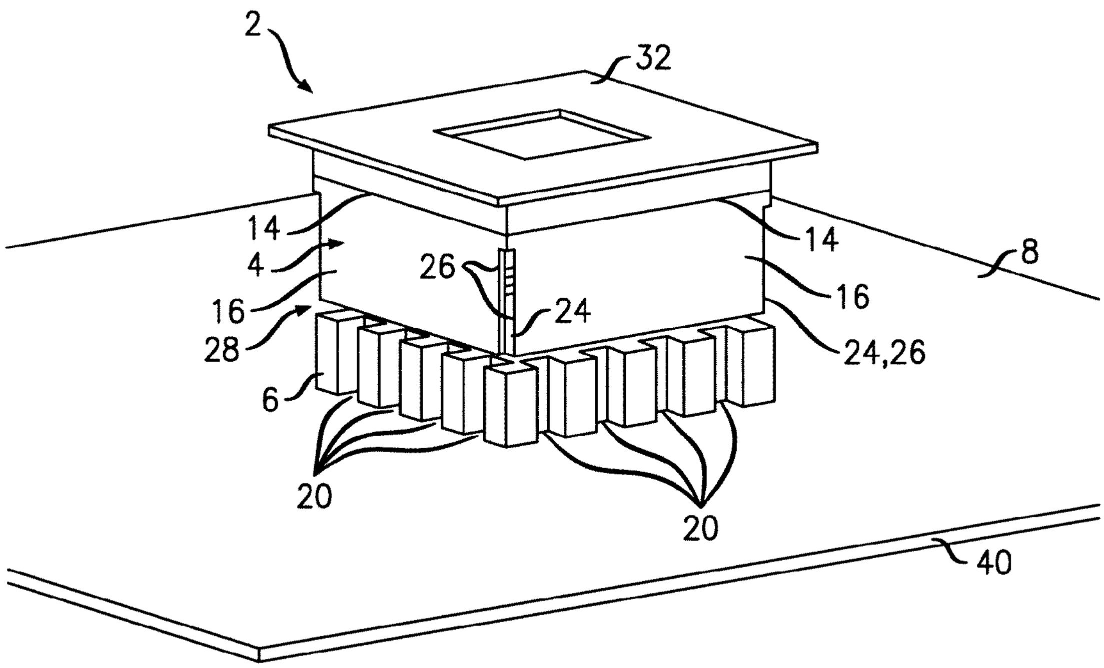
2
32
14
14
4
26
8
16
24
16
28
24,26
6
20
20
40

FIG. 1

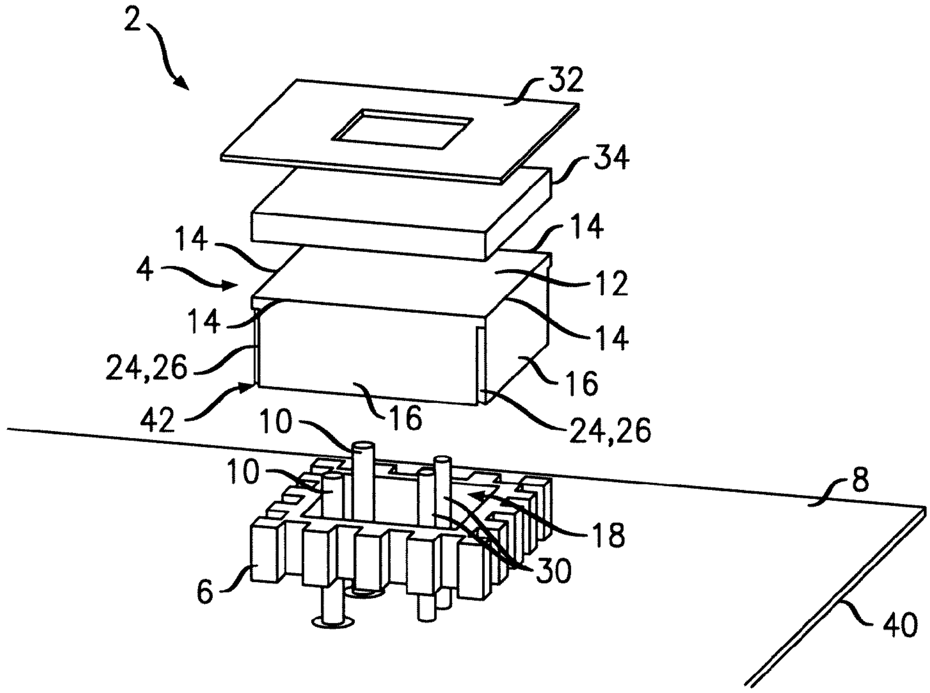
2
32
34
14
14
4
12
14
14
24,26
16
42
10
16
24,26
10
8
18
30
6
40

FIG. 2

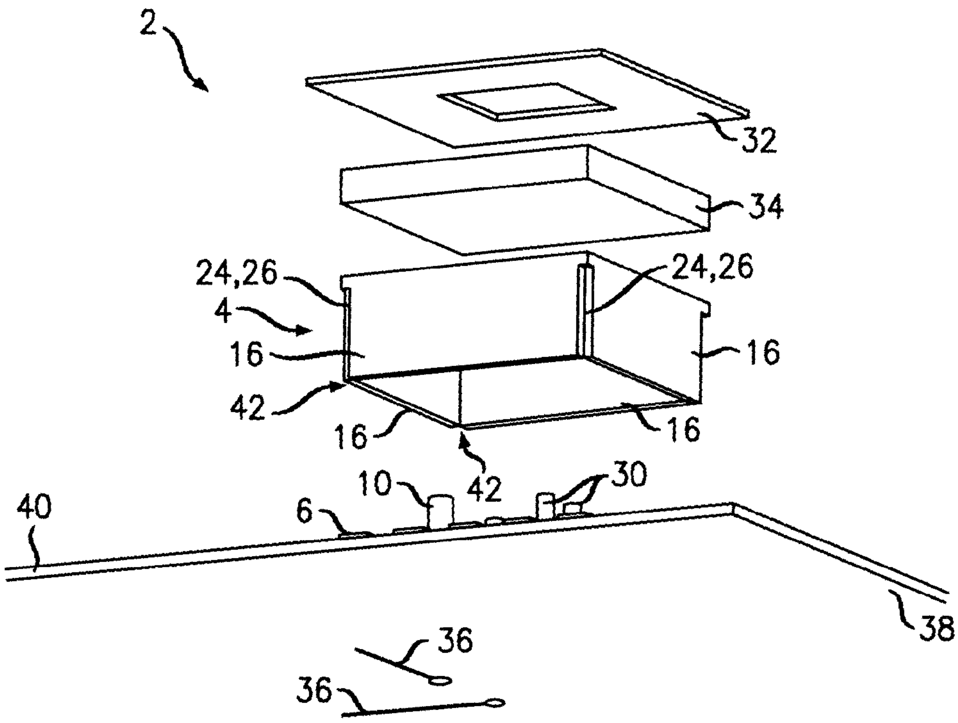
2
32
34
24,26
24,26
4
16
16
42
16
16
42
10
30
40
6
38
36
36

FIG. 3

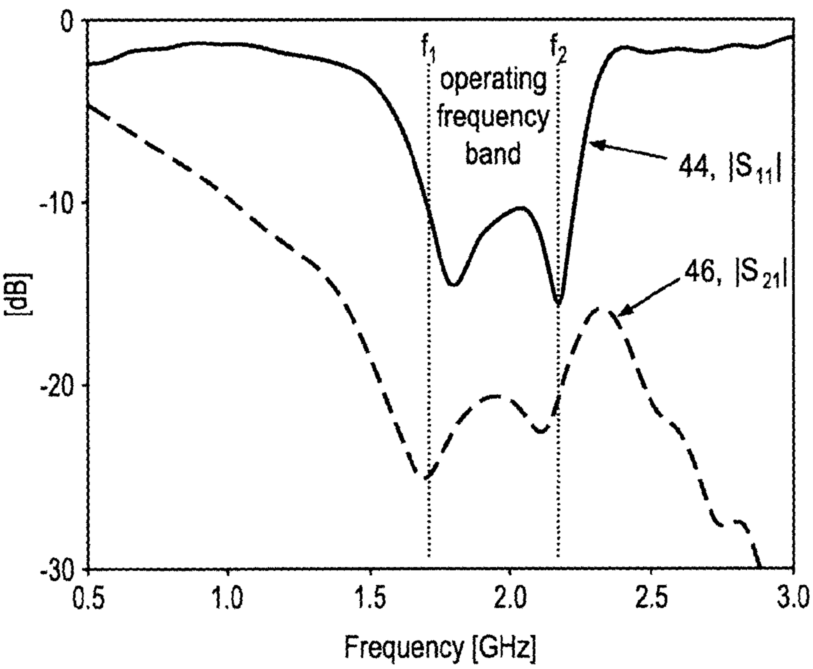
0
-10
-20
-30
[dB]
f_1
f_2
operating
frequency
band
44, $|S_{11}|$
46, $|S_{21}|$
0.5
1.0
1.5
2.0
2.5
3.0
Frequency [GHz]

FIG. 4

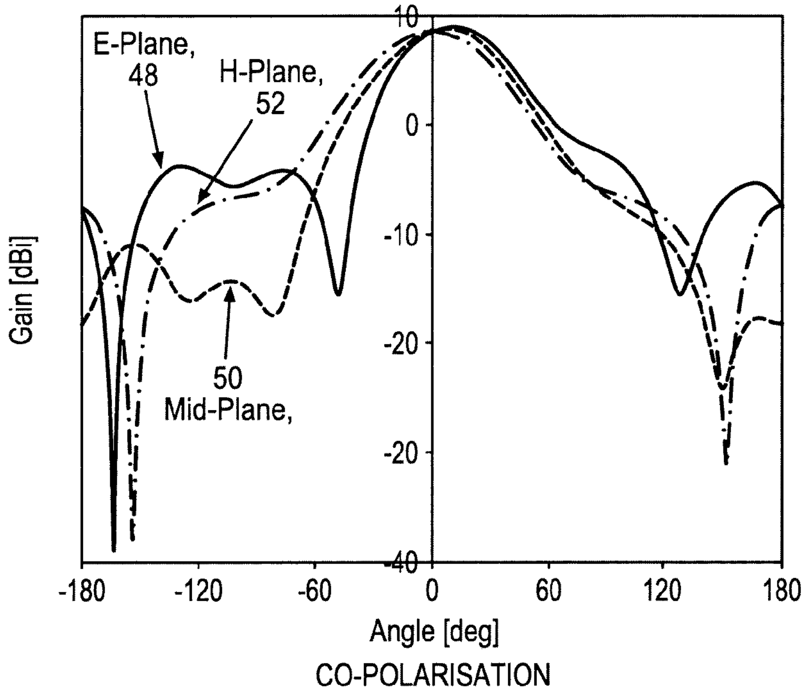
E-Plane,
48
H-Plane,
52
50
Mid-Plane,
10
0
-10
-20
-20
-40
-180
-120
-60
0
60
120
180
Gain [dBi]
Angle [deg]
CO-POLARISATION

FIG. 5

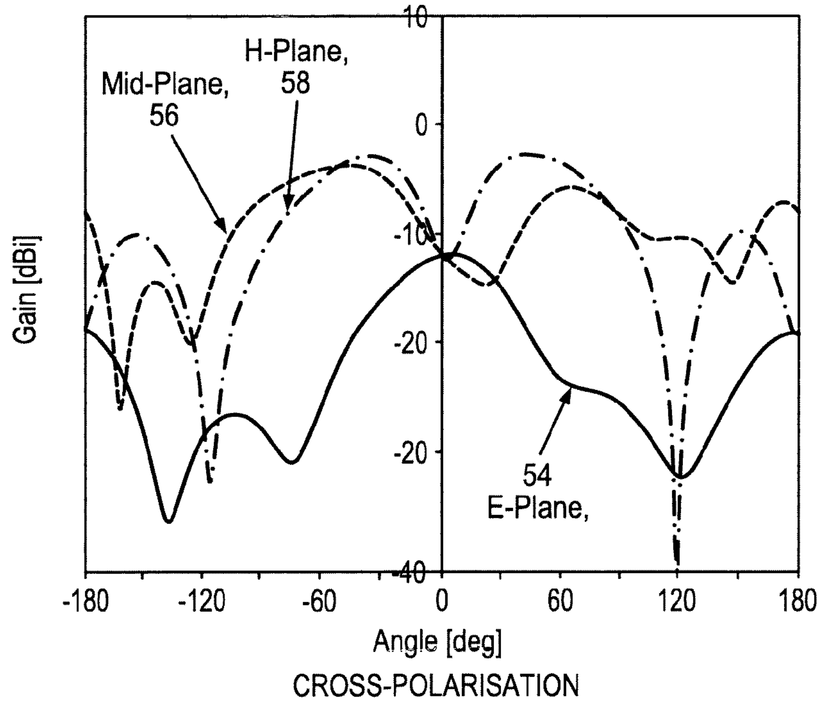
Mid-Plane,
56
H-Plane,
58
54
E-Plane,
10
0
-10
-20
-20
-40
-180
-120
-60
0
60
120
180
Gain [dBi]
Angle [deg]
CROSS-POLARISATION

FIG. 6

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 14 29 0052

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2011 117690 B3 (KATHREIN WERKE KG [DE]) 20 December 2012 (2012-12-20) * paragraphs [0058] - [0084], [0122] - [0125]; figures 1,2,7 * -----	1-15	INV. H01Q21/06 H01Q9/04 H01Q9/42
X	EP 1 933 416 A1 (ALPS ELECTRIC CO LTD [JP]) 18 June 2008 (2008-06-18) * paragraphs [0017], [0018]; figure 1 * -----	1-3,7,15	
X	US 5 633 646 A (STRICKLAND PETER C [CA]) 27 May 1997 (1997-05-27) * column 1, line 64 - column 3, line 45; figures 1-4 * -----	1,3,8, 12-15	
X	US 2008/074327 A1 (NORO JUNICHI [JP] ET AL) 27 March 2008 (2008-03-27) * paragraphs [0087] - [0110]; figure 1 * -----	1,3,14, 15	
X	US 2009/303133 A1 (UEKI NORIYUKI [JP]) 10 December 2009 (2009-12-10) * paragraphs [0058] - [0062]; figure 1 * -----	1,3,14, 15	TECHNICAL FIELDS SEARCHED (IPC) H01Q

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	18 July 2014	van Norel, Jan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 14 29 0052

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

18-07-2014

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102011117690 B3	20-12-2012	NONE	
EP 1933416 A1	18-06-2008	CN 101202375 A	18-06-2008
		EP 1933416 A1	18-06-2008
		TW 200832810 A	01-08-2008
		US 2008143608 A1	19-06-2008
US 5633646 A	27-05-1997	CA 2182334 A1	12-06-1997
		US 5633646 A	27-05-1997
US 2008074327 A1	27-03-2008	NONE	
US 2009303133 A1	10-12-2009	CN 101558531 A	14-10-2009
		JP 4807413 B2	02-11-2011
		US 2009303133 A1	10-12-2009
		WO 2008072411 A1	19-06-2008

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Non-patent literature cited in the description

- **T. A. MILLIGAN.** Modern Antenna Design. John Wiley & Sons, 2005, 255 **[0005]**
- **K.-L. WONG.** Compact and Broadband Microstrip Antennas. John Wiley & Sons, 2002, 1-7 **[0006]**
- **J. A. NAVARRO et al.** A 29.3 GHz cavity-enclosed aperture-coupled circular patch antenna for microwave circuit integration. *IEEE Microwave and Guided Wave Letters,* July 1991, vol. 1 (7), 170-171 **[0008]**
- **B. A. BRYNJARSSON ; T. SYVERSEN.** Cavity-enclosed, aperture coupled microstrip patch antenna. *IEE 1993 International Conference on Antennas and Propagation Symposium Proceedings,* March 1993, vol. 2, 715-718 **[0008]**
- **P. INGVARSON et al.** Patch-excited cup elements for satellite-based mobile communication antennas. *2000 IEEE International Conference on Phrased Array Systems and Technology, Dana Point, CA,* May 2000, 215-218 **[0008]**