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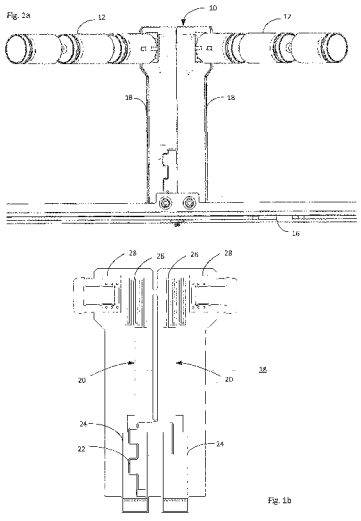
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(54) Title: FULL WAVE DIPOLE ARRAY HAVING IMPROVED SQUINT PERFORMANCE



(57) Abstract: A cellular base station antenna having improves squint performance is provided. The antenna includes a ground plane, a first plurality of radiating elements supported over the ground plane by microstrip support PCBs, and a second plurality of radiating elements supported over the ground plane by stripline support PCBs. The first and second pluralities of radiating elements are arranged in at least one array of low band radiating elements, and the quantities of first and second pluralities of radiating elements are selected to reduce squint of a beam produced by the at least one array. The first plurality of radiating elements may be located below the second plurality of radiating elements in the array. The array may be arranged in a linear column or a staggered column. In one example, the first plurality of radiating elements comprises four radiating elements and the second plurality radiating elements comprises two radiating elements.

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FULL WAVE DIPOLE ARRAY HAVING IMPROVED SQUINT PERFORMANCE

Statement of Related Applications

This application claims priority to U.S. Provisional Patent Application Serial No. 62/120,689, filed February 25, 2015, the disclosure of which is incorporated by reference.

Field of the Invention

The present invention relates to antennas comprising arrays of radiating elements. In particular, the present invention provides improved squint performance for arrays of radiating elements.

Background

Arrays of full wave dipole radiating elements have been observed to suffer from squint at high electrical down tilt angles. The term "squint" means the amount that a beam peak (midpoint between -3dB angles) deviates from boresight of the antenna. See, for example, Figure 9, which illustrates an azimuth beam pattern having approximately 12° of squint. A "full wave" dipole radiating element is a type of dipole that is designed such that its second resonant frequency is in the desired frequency band. In this type of dipole, the dipole arms are dimensioned such that the two dipole arms together span about three-quarters to one full wavelength of the desired operational frequency band. This is in contrast to "half-wave" dipoles, where the dipole arms are about one quarter wavelength of the operating band, and the two dipole arms together have a length of about one half the wavelength of the operating band.

While full wave dipoles have certain advantages in low band arrays of radiating elements in a multi-band array, known arrays of full wave dipoles typically experience disadvantageous

coupling between two adjacent -45 degree polarization dipoles and +45 degree polarization dipoles, which may cause cross polarization and squint degradation at certain frequencies (referred to herein as "squint resonance frequency"). This effect particularly happens for the vertical polarization component of a slant dual-polarized dipole.

What is needed is an array of full wave dipole radiating elements with improved squint performance.

Summary of the Invention

A cellular base station antenna having improves squint performance is provided. The antenna includes a ground plane, a first plurality of radiating elements supported over the ground plane by microstrip support PCBs, and a second plurality of radiating elements supported over the ground plane by stripline support PCBs. The first and second pluralities of radiating elements are arranged in at least one array of low band radiating elements, and the quantities of microstrip PCB elements and stripline PCB elements are selected to minimize squint of a beam pattern provided by the array. The first plurality of radiating elements may be located below the second plurality of radiating elements in the array. The array may be arranged in a linear column or a staggered column. In one example, the first plurality of radiating elements comprises four radiating elements and the second plurality radiating elements comprises two radiating elements.

In a preferred embodiment, the first and second pluralities of radiating elements comprise low band radiating elements of a multi-band antenna. The low band radiating elements may be full wave cross dipole radiating elements. The cellular base station antenna may further include at least one array of high band radiating elements. In another example, a second array of microstrip support PCB and stripline support PCB radiating elements may be provided.

The microstrip support PCBs may each comprise a hook balun, a feed stalk, an inductive section, and a capacitive section. The stripline support PCBs may each comprise a hook balun, at least two feed stalks sandwiching the hook balun, an inductive section, and a capacitive section.

Brief Description of the Drawings

Figure 1a is a side view of a low band radiating element having a microstrip support PCB which may be used in combination with additional elements to provide an antenna array according to one aspect of the present invention.

Figure 1b is a detailed view of microstrip support PCB of the low band element of Figure 1a.

Figure 2 illustrates squint performance of an antenna array which is composed solely of radiating elements and microstrip support PCBs as illustrated in Figures 1a and 1b.

Figure 3a is a side view of a low band radiating element having a stripline support PCB which may be used in combination with additional elements to provide an antenna array according to one aspect of the present invention.

Figures 3b and 3c are a detailed views of the stripline support PCB of the low band element of Figure 3a.

Figure 4 illustrates squint performance of an array which is composed solely of radiating elements and stripline support PCBs as illustrated in Figures 3a-3c.

Figure 5 is a side view of an array of radiating elements according to one aspect of the present invention.

Figure 6 is a side view of a portion of an antenna comprising high band and low band arrays of radiating elements according to another aspect of the present invention.

Figure 7 is a simplified plan view of an antenna comprising high band and low band arrays of radiating elements according to another aspect of the present invention.

Figure 8 illustrates squint performance of an array of radiating elements and feed circuits according to another aspect of the present invention.

Figure 9 is an illustration of squint of a known array of low band elements.

Detailed Description of the Invention

Figure 1a illustrates one example of a microstrip support PCB radiating element 10. The microstrip support PCB radiating element 10 includes low band dipole arms 12 supported over a reflector 16 by microstrip support PCBs 18. In the illustrated examples, low band dipole arms 12 comprise full wave dipoles, which span from about three-quarters to one full wavelength of an operating frequency band of microstrip support PCB radiating element 10. Optionally, the low band dipole arms 12 include RF chokes that are resonant at high band frequencies to minimize scattering of high band elements. See, e.g., International Pat. Pub. No. WO 2014100938, (the "'938 Application."), which is incorporated by reference.

In the microstrip support PCB radiating element 10, the low band dipole arms 12 are excited by microstrip support PCBs 18 (Fig. 1b). The term "microstrip," as used herein, has its conventional meaning of a conducting strip separated from a ground plane by a dielectric layer, often fabricated on a printed circuit board. The microstrip construction in this example comprises feed circuit 20 and a hook balun 22. Each feed circuit 20 comprises a feed stalk 24, an inductive section 26, and a capacitive section 28.

Figure 1b illustrates the metallization layers of one of the microstrip support PCBs 18 of the microstrip support PCB radiating element 10 of Figure 1a. The hook balun 22 is connected to an array feed network of an antenna. The array feed network may comprise a conventional corporate feed network. Optionally, the array feed network includes variable phase shifters to adjust relative phase relationships between radiating elements, thereby adjusting an electrical downtilt angle of the array. The hook balun 22 then couples the RF signals from the feed network to a feed circuits 20 on the microstrip support PCB 18. Unbalanced RF signals from the feed network are coupled into feed stalks 24 as balanced signals. Each feed stalk 24 is coupled to a capacitive section 28 for coupling to the low band dipole arms 12 by way of the inductive section 26, which is included for impedance matching.

Figure 2 illustrates squint degradation for an array of five full-wave, low band, microstrip support PCB radiating element 10 excited by microstrip support PCBs 18. Squint degradation increases as electrical downtilt angle increases, and the microstrip support PCB elements exhibit squint resonance frequencies at 738MHz and 935 MHz. For example, squint exceeds 15° for 15° of downtilt for +45° polarization at 935 MHz, and approaches 15° for the -45° polarization. At 10° electrical downtilt, squint exceeds 5° for much of the band.

Figure 3a illustrates a second example of a full wave low band dipole radiating element comprising a stripline support PCB radiating element 30. This second example has a stripline support PCB 38 in place of the microstrip support PCB 18 of Figures 1a and 1b. The term "stripline," as used herein, has its conventional meaning of a conducting strip sandwiched between, and separated from, two ground planes by dielectric layer(s), once again, often fabricated on a printed circuit board (PCB). In the illustrated example, the stripline support PCB radiating element 30 includes low band dipole arms 12 supported over reflector 16 by stripline

support PCBs 38. Figure 3b and 3c illustrate metallization layers for one of the stripline support PCBs 38 of the stripline support PCB radiating element 30 of Figure 3a. The stripline construction in this example comprises a hook balun 42 sandwiched between two layers of feed stalks 44a, 44b. Each stripline feed circuit 40 comprises feed stalks 44a, 44b, inductor sections 46, and capacitive sections 48.

Figure 4 illustrates squint degradation for an array of five stripline support PCB radiating elements 30 having full wave, low band dipole arms 12 excited by stripline support PCBs. Squint degradation increases as electrical downtilt angle increases, and the stripline feed stalk cross-talk elements exhibit a squint resonance frequency at 824MHz. For example, squint exceeds 15° for 15° electrical downtilt at 824MHz for both polarizations. At 10° electrical downtilt, squint exceeds 5° for much of the band.

A cellular base station antenna array having improved squint performance is now described. As used herein, "cellular" includes any type of singe point to multi-point wireless communications technology, including but not limited to, TDMA, GSM, CDMA, and LTE wireless air interfaces. "Base station antenna" includes, but is not limited to, cellular macro sites and Distributed Antenna Systems (DAS).

Referring to Figure 5, a portion of a cellular base station antenna viewed from the side is illustrated. A plurality of microstrip support PCB radiating elements 10 and stripline support PCB radiating elements 30 are arranged in a linear array 60 over a reflector 16. The two bottom (leftmost in the illustration) microstrip support PCB radiating elements 10 employ full wave, low band dipole arms 12 and microstrip support PCBs 18 as illustrated in figures 1a and 1b. The four top radiating elements (rightmost in the illustration) are stripline support PCB radiating element 30 employing full wave, low band dipole arms 12 and stripline support PCBs 38 as illustrated in

figures 3a-3c. Figure 6 illustrates a portion of the base station antenna of Figure 5 enlarged to reveal more detail with one microstrip support PCB element 10 and one stripline support PCB radiating element 30. Also illustrated are a plurality of high band elements 50 interspersed between the microstrip support PCB radiating elements 10 and stripline support PCB radiating elements 30.

Figure 7 is a schematic diagram of a dual band antenna implementing an example of the present invention. In this example, there is a single linear array 60 of low band elements, and two linear arrays 62 of high band elements, one on either side of the low band array. In this view, as in Figure 5, the bottom two radiating elements comprise microstrip support PCB radiating elements 10 including microstrip support PCBs 18 and the top four radiating elements comprise stripline support PCB radiating elements 30 including stripline support PCBs 38. While a two microstrip/four stripline radiating element combination is illustrated in the present example, different combinations may be employed to achieve desired results. For example, longer antennas may be employed using additional elements to shape elevation beamwidth, and as a result different combinations of elements would be necessary. Also, changes to power distribution across the linear array (e.g., power taper) may also affect the optimal mix of stripline and microstrip elements. Also, while a single column of low band radiating elements may be sufficient to provide a 65°HPBW radiation pattern, additional columns of low band elements or a staggered linear array of low band elements may be employed to widen the aperture and produce narrower beam widths. Additionally, multi-column arrays may be employed in multi-beam antennas.

Referring to Figure 8, the combination of stripline and microstrip support PCBs in an array of radiating elements results in squint performance that is improved compared to using

either all stripline support PCBs or all microstrip PCBs. For example, squint is well below 15° at all frequencies at 15° of downtilt. Squint rarely exceeds 5° for other values of downtilt measured (7° and 0°). The combination of full wave dipoles and a mix of microstrip and strip line support PCBs may be advantageously used in a multiband, ultra-wideband antenna, such as the dual-band base station antenna of the '938 Application.

In view of the many possible embodiments to which the principles of the disclosed invention may be applied, it should be recognized that the illustrated embodiments are only preferred examples of the invention and should not be taken as limiting the scope of the invention. Rather, the scope of the invention is defined by the following claims. We therefore claim as our invention all that comes within the scope of these claims.

What is claimed is:

1. A cellular base station antenna comprising:

a. a ground plane;

b. a first plurality of radiating elements supported over the ground plane by microstrip support PCBs; and

c. a second plurality of radiating elements supported over the ground plane by stripline support PCBs;

wherein the first and second pluralities of radiating elements are arranged in at least one array of low band radiating elements.

2. The cellular base station antenna of claim 1, wherein the first plurality of radiating elements is located below the second plurality of radiating elements.

3. The cellular base station antenna of claim 2, wherein the first plurality of radiating elements comprises four radiating elements and the second plurality radiating elements comprises two radiating elements.

4. The cellular base station antenna of claim 1, wherein the first and second pluralities of radiating elements comprise full wave cross dipole radiating elements.

5. The cellular base station antenna of claim 1, wherein the first and second pluralities of radiating elements comprise low band radiating elements, the cellular base station antenna further comprising at least one array of high band radiating elements.

6. The cellular base station antenna of claim 1, further comprising:

a. a third plurality of radiating elements supported over the ground plane by microstrip support PCBs; and

b. a fourth plurality of radiating elements supported over the ground plane by stripline support PCBs;

wherein the third and fourth pluralities of radiating elements are arranged in a second array of radiating elements.

7. The cellular base station antenna of claim 1, wherein the quantities of first and second pluralities of radiating elements are selected to reduce squint of a beam produced by the at least one array.

8. A cellular base station antenna comprising:

a. a ground plane;

b. a first plurality of low band full wave dipole radiating elements supported over the ground plane by microstrip support PCBs;

c. a second plurality of low band full wave dipole radiating elements supported over the ground plane by stripline support PCBs; and

d. at least one array of high band radiating elements;

wherein the first and second pluralities of radiating elements are arranged in at least one array of low band radiating elements.

9. The cellular base station antenna of claim 8, wherein the first plurality of radiating elements is located below the second plurality of radiating elements.

10. The cellular base station antenna of claim 8, wherein the microstrip support PCBs each comprise a hook balun, a feed stalk, an inductive section, and a capacitive section.

11. The cellular base station antenna of claim 8, wherein the stripline support PCBs each comprise a hook balun, at least two feed stalks sandwiching the hook balun, an inductive section, and a capacitive section.

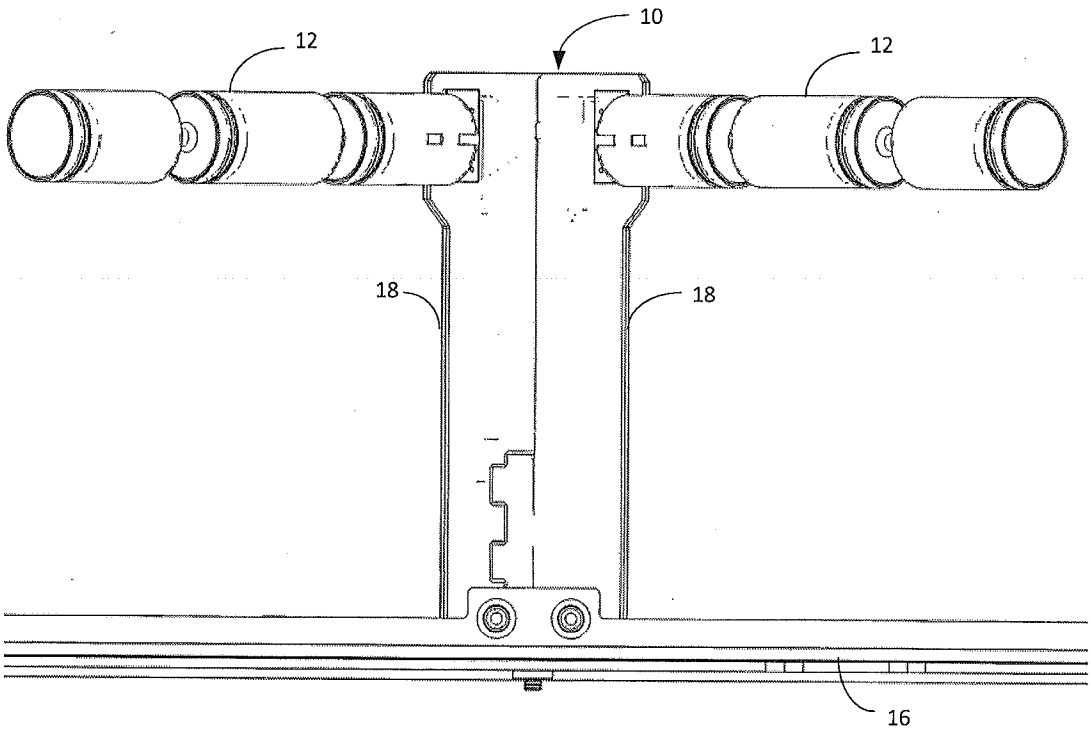


Fig. 1a

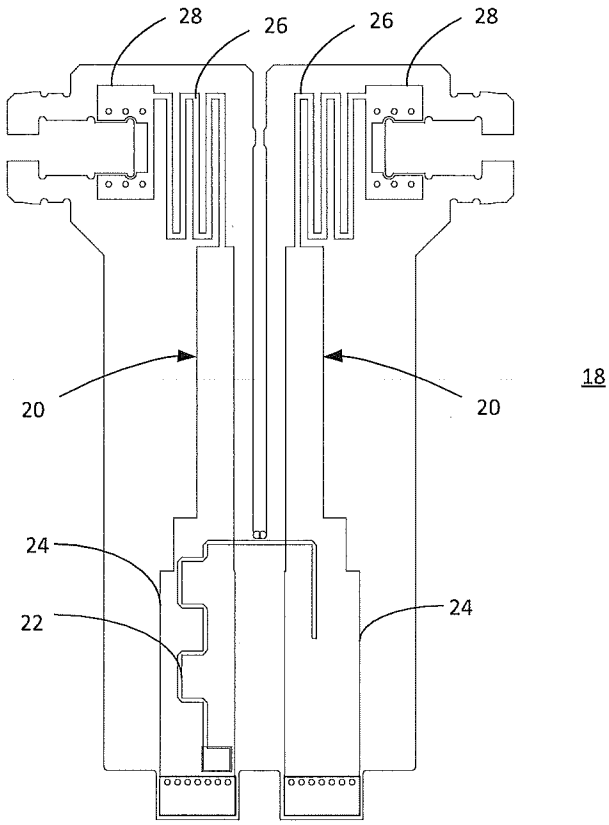


Fig. 1b

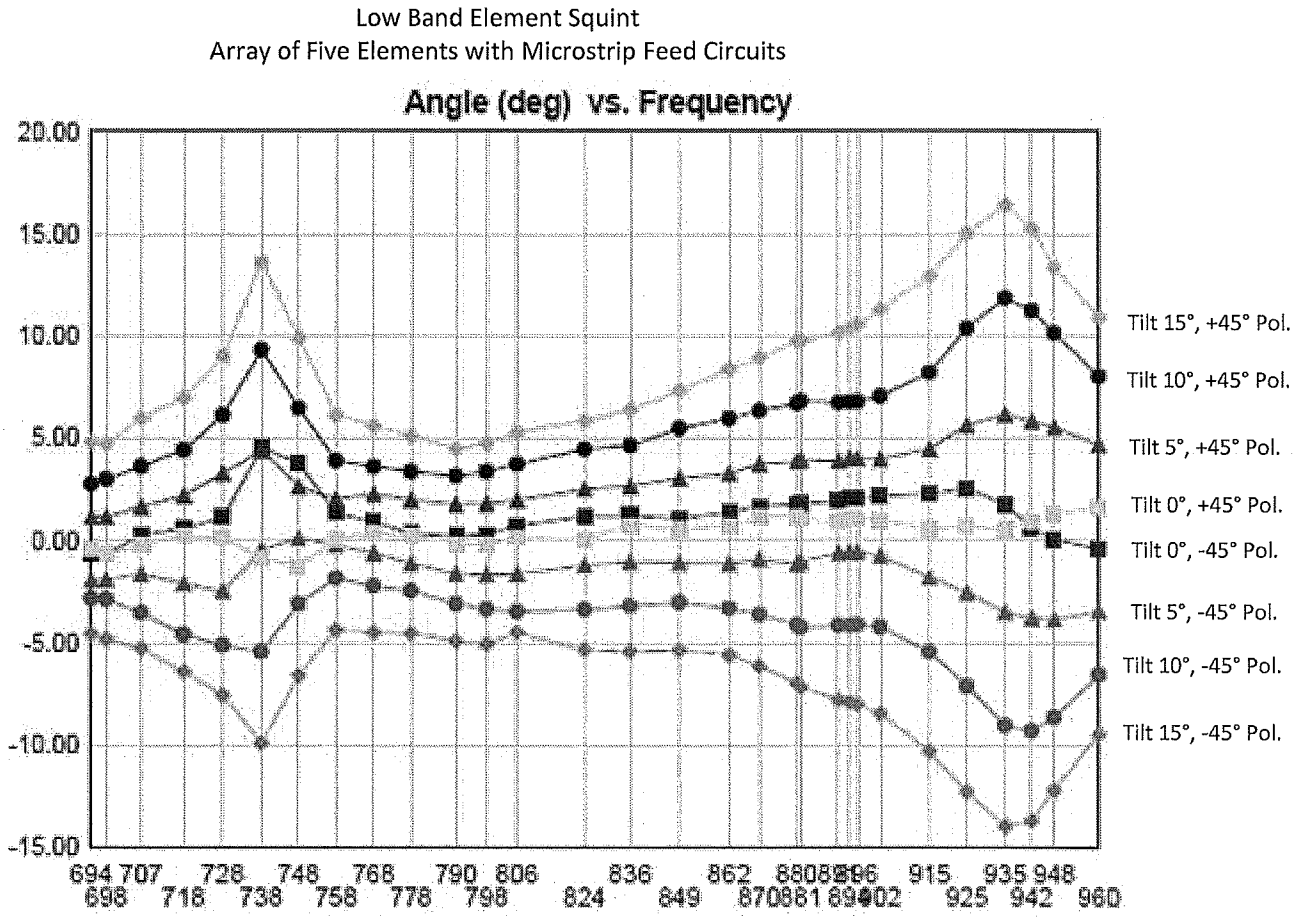

Low Band Element Squint
Array of Five Elements with Microstrip Feed Circuits
Angle (deg) vs. Frequency
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
694 707 728 748 768 790 806 836 862 915 935 948
698 718 738 758 778 798 824 849 925 942 960
Tilt 15°, +45° Pol.
Tilt 10°, +45° Pol.
Tilt 5°, +45° Pol.
Tilt 0°, +45° Pol.
Tilt 0°, -45° Pol.
Tilt 5°, -45° Pol.
Tilt 10°, -45° Pol.
Tilt 15°, -45° Pol.

Fig. 2

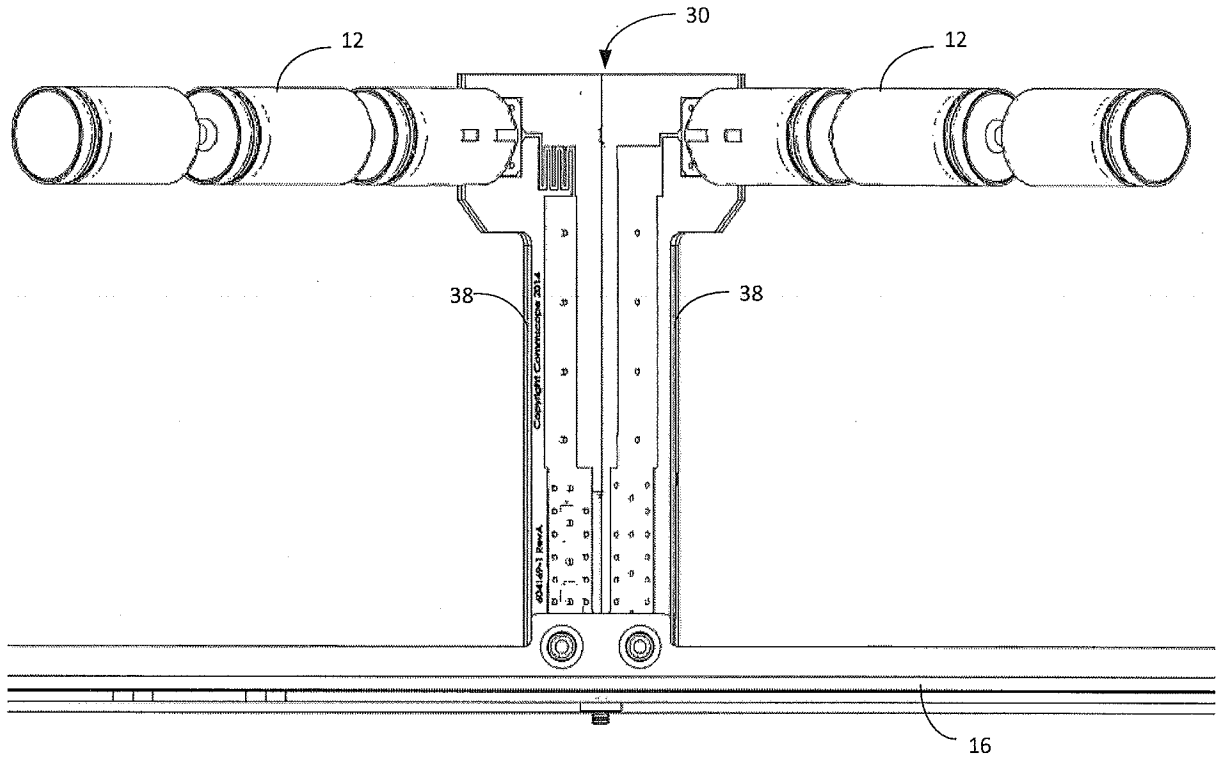


Fig. 3a

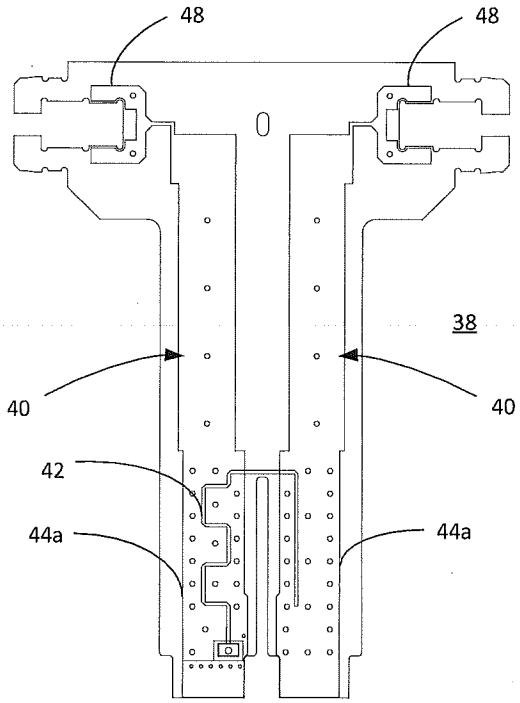


Fig. 3b

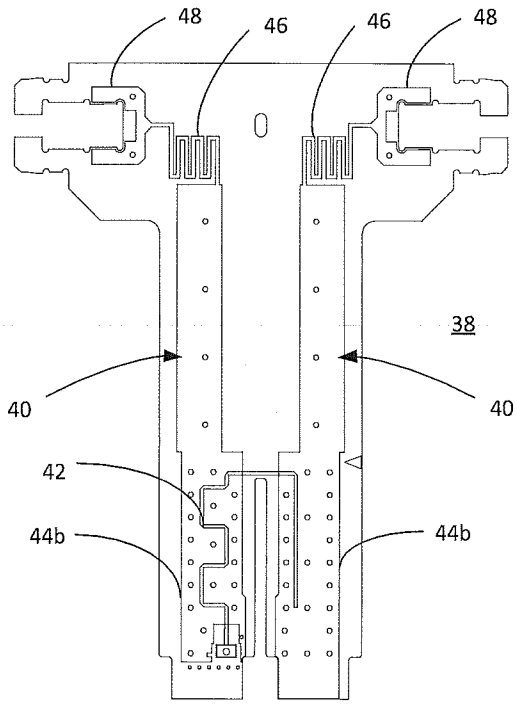


Fig. 3c

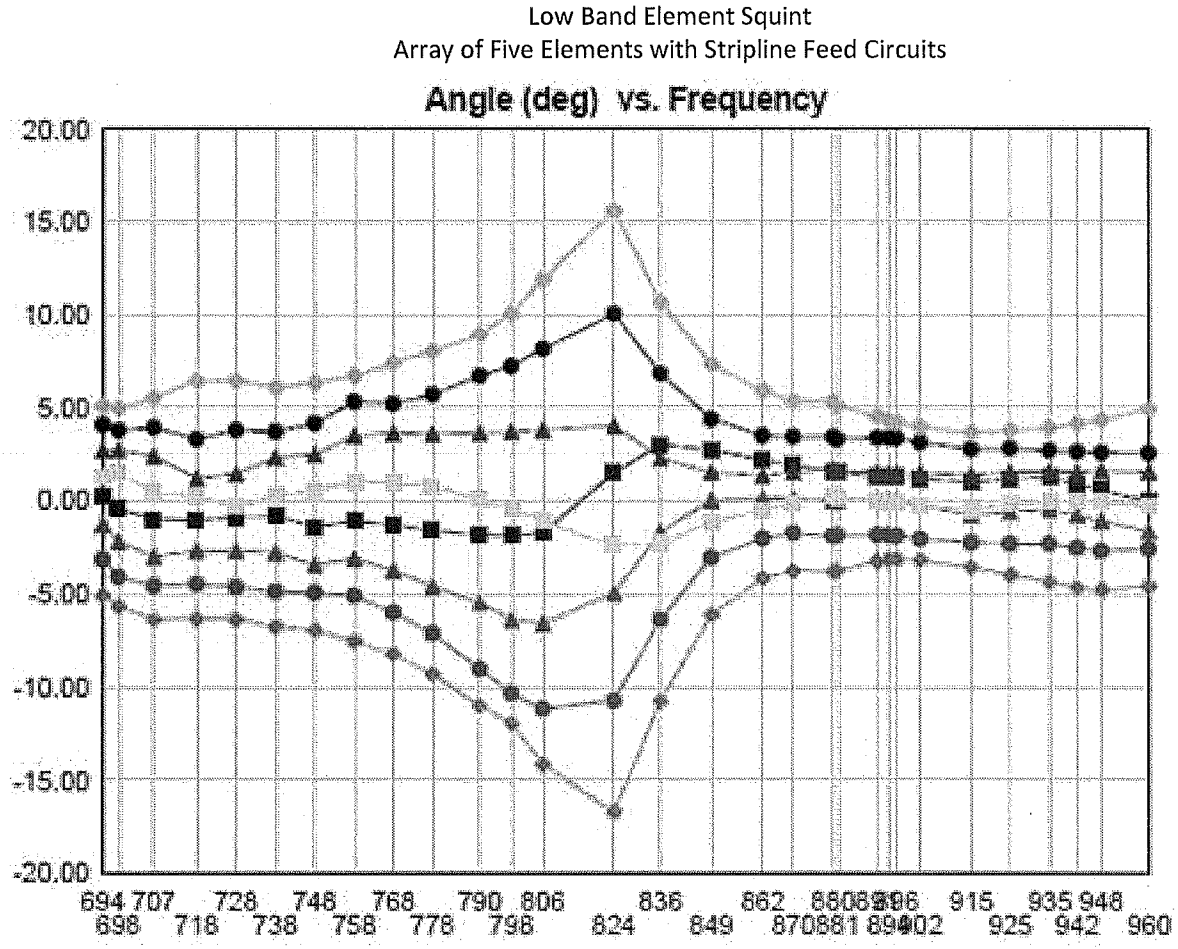

Low Band Element Squint
Array of Five Elements with Stripline Feed Circuits
Angle (deg) vs. Frequency
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
694 707 728 748 768 790 806 836 862 915 935 948
698 718 738 758 778 798 824 849 925 942 960

Fig. 4

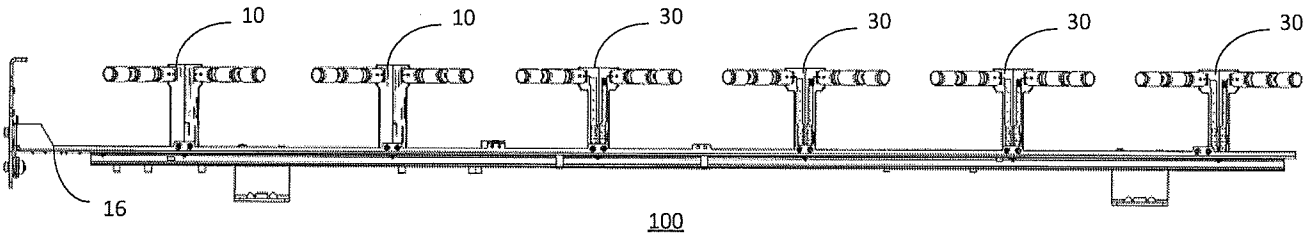


Fig. 5

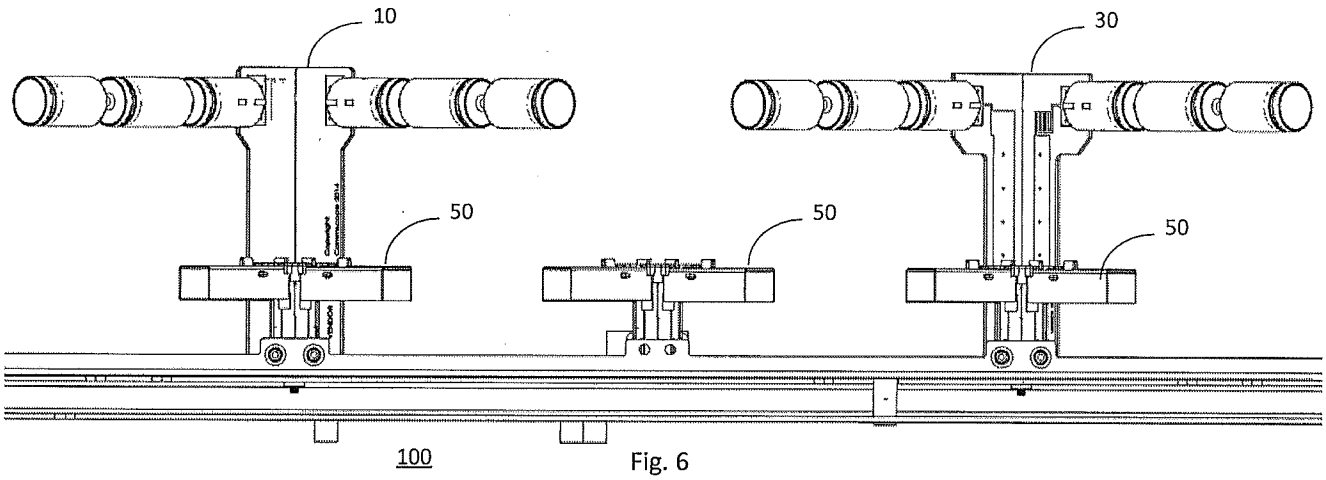


Fig. 6

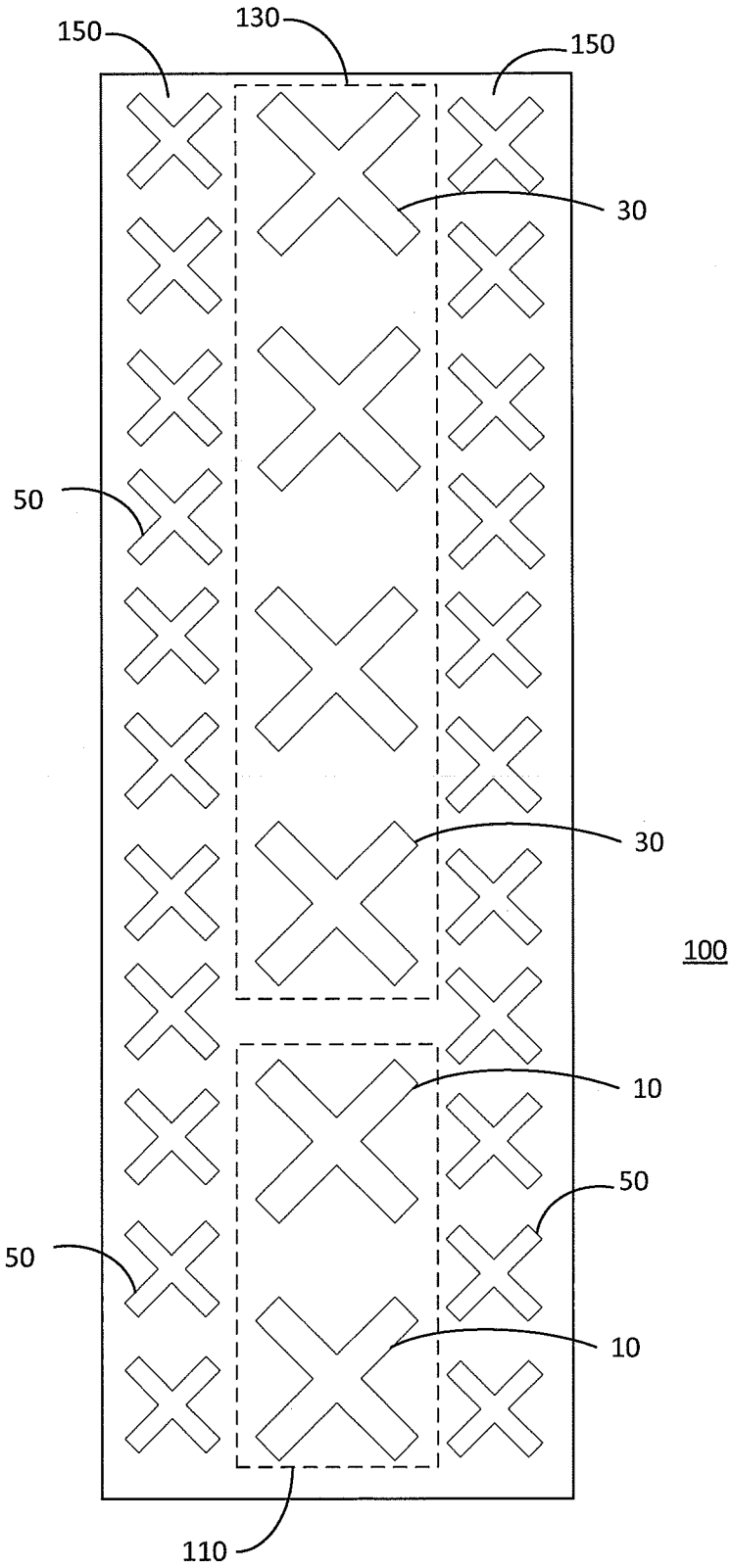
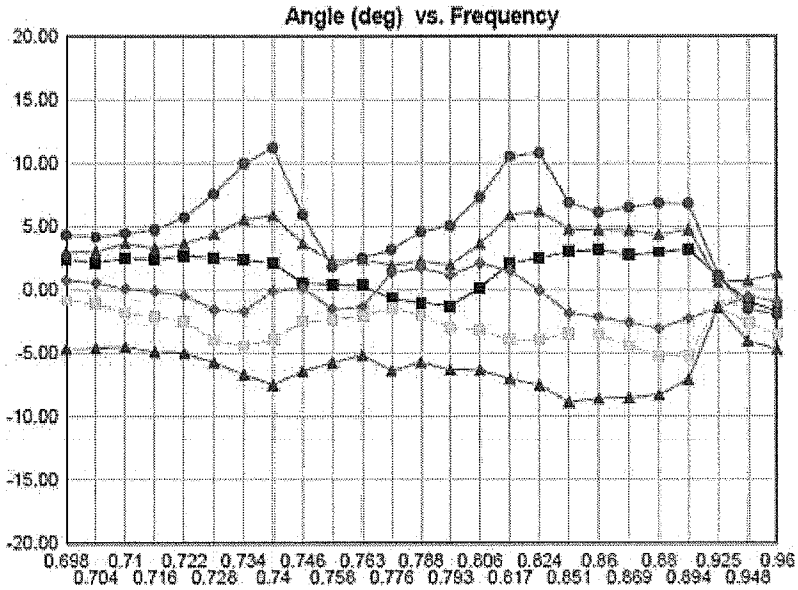


Fig. 7



Name		Min	Max	Mean	Stdv	Tol
Overall		-8.89	11.24	0.12	4.32	6.48
LB_LP_T0		-1.75	3.16	1.40	1.55	2.32
LB_LP_T7		0.62	6.16	3.53	1.56	2.34
LB_LP_T15		-2.00	11.24	5.38	3.35	5.02
LB_RP_T0		-3.06	2.09	-0.51	1.41	2.12
LB_RP_T7		-5.29	-0.67	-3.00	1.22	1.82
LB_RP_T15		-8.88	-1.43	-6.09	1.67	2.51

Fig. 8

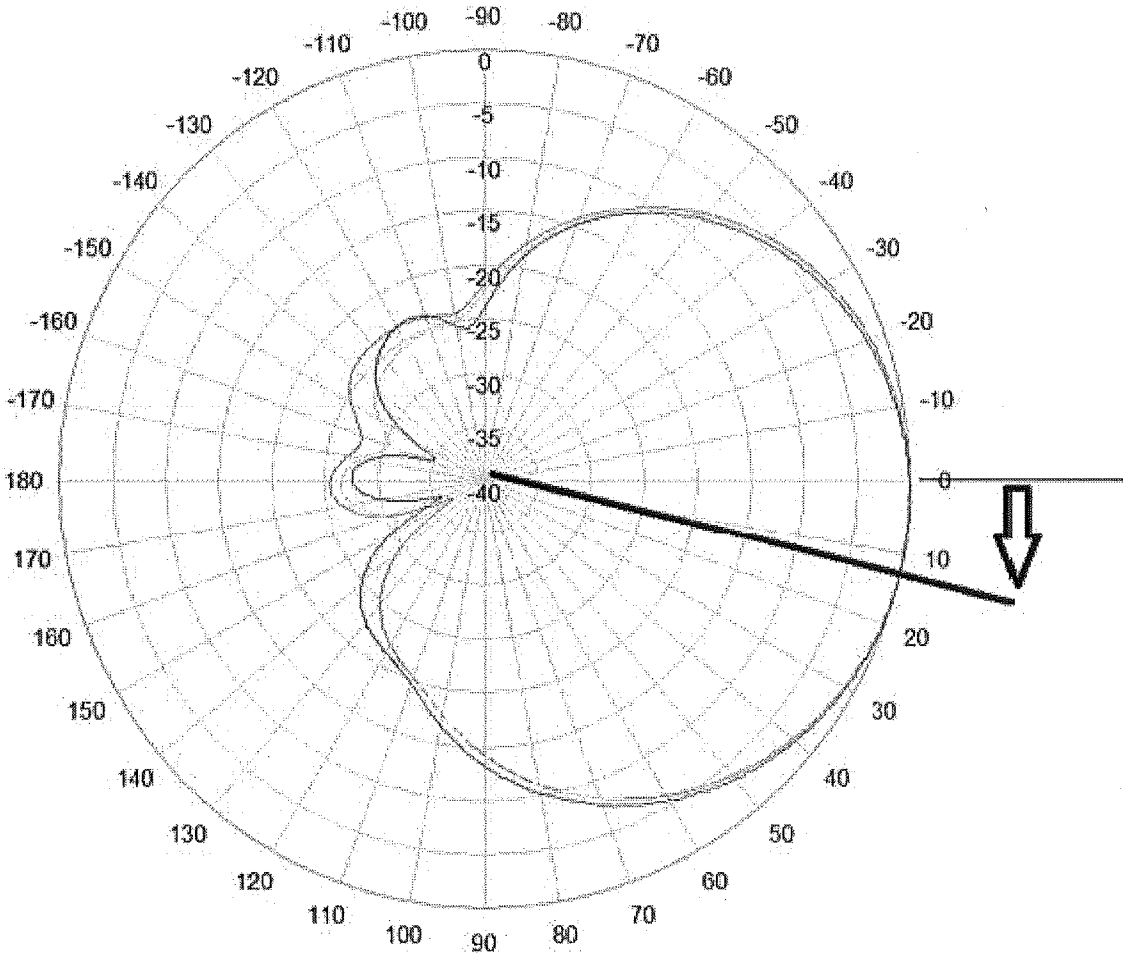

-100
-90
-80
-110
-70
-120
-60
-130
-50
-140
-40
-150
-30
-160
-20
-170
-10
180
0
170
10
160
20
150
30
140
40
130
50
120
60
110
70
100
90
80
0
-5
-10
-15
-20
-25
-30
-35
-40

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/039742

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01Q1/24 H01Q21/00 H01Q21/06 H01Q21/08 H01Q5/40
H01Q9/18
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2005/122331 A1 (ANDREW CORP [US]) 22 December 2005 (2005-12-22)	1-5,7-9
Y	page 9 - page 10; figure all page 15, line 1 - line 8 page 23, line 10 - line 24	6,10,11

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
29 October 2015	10/11/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Wattiaux, Véronique

1

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DOANE JONATHAN P ET AL: "A Wideband, Wide Scanning Tightly Coupled Dipole Array With Integrated Balun (TCDA-IB)", IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 61, no. 9, 1 September 2013 (2013-09-01), pages 4538-4548, XP011525653, ISSN: 0018-926X, DOI: 10.1109/TAP.2013.2267199 [retrieved on 2013-08-30]	1-3
Y	figure 9	6,10,11

X	US 2014/028516 A1 (SEMONOV KOSTYANTYN [US] ET AL) 30 January 2014 (2014-01-30) paragraph [0025] paragraph [0029] - paragraph [0031] figure all	1

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/039742

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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