

MULTIPLE-RESONANT-MODE DUAL POLARIZED ANTENNA

FIELD OF THE INVENTION

The present invention relates to a dual polarized antenna. More particularly, the
5 present invention relates to antennas emitting or receiving two orthogonal polarizations such as vertical and horizontal or +/-45 degree slants.

DESCRIPTION OF RELATED ART

One of the first dual polarized antennas is described in US3740754, wherein two
10 dipoles made of metal tubes are disposed at right angles to each other above a reflecting cap and fed by two pairs of coaxial lines. Subsequently, hundreds of different dual polarized antennas were invented to increase operating frequency band.

15 US4184163 describes a broad band dual polarized antenna wherein dipole arms are made of metal loops having a ring or square frame. US5481272, US5952983, US6028563 and US6072439 describe several types of dipoles including folded grid dipoles, bow tie dipoles, and dipoles with an attached printed circuit board balun.

20 Several kinds of crossed dipoles containing radiating arms formed of two branches to decrease beam width are described in US6747606B2, US2005/0253769A1, US2013/0106668A1, CN201435451Y, CN102025023A, CN201845867U and CN102074781A.

25 As crossed dipoles create a wide beam at the horizontal (H) plane, more complicated radiators were invented to decrease beam width. US5940044 describes a dual slant polarized antenna having approximately 65 degrees half power beam width in the horizontal plane. This antenna includes a plurality of dipole sub-arrays with each sub-array comprising four dipoles arranged in a diamond shape. Two dipoles of each
30 sub-array are tilted at an angle of +45 degrees from the long edge of the ground plate to form a +45 degree polarized radiating element array. The other two dipoles are arranged at an angle -45 degrees from the long edge of the ground plate to form a -45 degree polarized radiating element array. The dipoles are arranged such that the phase centers of one +45 degree dipole and one -45 degree element line up
35 along a first vertical line which is parallel to the long edge of a ground plate. The phase centers of the other + 45 degree dipole and -45 degree element line up along a second vertical line. The main disadvantage of this dipole square is the

complicated feed network. For example, four cables have to be used for feeding the dipoles.

5. EP0973231A2, US6333720B1, US6529172B2 and US2010/0309084A1 describe radiators having a dipole square shape. Baluns of the same dipoles are tilted to the center of the dipole square to simplify manufacturing. In spite of this new shape, these devices are still complicated.

US6313809B1 describes a dual polarized radiator comprising four dipoles preferably arranged above a reflector and forming a dipole square structurally in the top view.
 10 Each dipole is fed by means of a symmetrical line characterized by the following features. The radiator radiates electrically in polarizations at an angle of +45 or -45 degrees to the structurally prescribed alignment of dipoles. The ends of symmetrical lines leading to the respective dipole halves are connected in such a way that the corresponding line halves of the adjacent, mutually perpendicular dipole halves are
 15 always electrically connected. The electric feeding of the respectively diametrically opposite dipole halves is performed in a decoupled fashion for a first polarization and a second polarization orthogonal thereto.

Other modifications of this dipole square are described in US6940465B2,
 20 US7688271B2, CN202423543U, CN202268481U, CN101916910A, CN102097677A, CN102694237A, CN102544711A, CN201199545Y, CN102117967A and CN102013560A.

WO2007/114620A1 describes a dual polarized radiator comprising four folded
 25 dipoles preferably arranged in the same way as dipoles of the radiator described in US6313809B1. Other modifications of a dipole square formed by four folded dipoles are described in CN101707292A, CN201430215Y, CN202178382U, and CN202004160U. Folded dipoles coupled with a dipole square by capacitive coupling are described in CN102377007A, CN201117803Y, CN201117803Y and
 30 CN101505007A.

Known radiators containing four usual or folded dipoles arranged as a dipole square provide good patterns at a frequency band up to 30% and operate well in a frequency band 1710-2170 MHz but cannot provide a cross polarization ratio better than -10 dB
 35 at edges of +/- 60 degree sector through a wider frequency band 1710-2690MHz. The length of dipoles is about half wave length corresponding to the middle operating frequency for matching with feeding line at the lowest operating frequency of 1710 MHz. Therefore a diagonal of a dipole square is almost wave length corresponding to

the highest operating frequency of 2690MHz. Thus, a distance between radiators of a dipole square is too big to keep a 65 degree beam width and equal horizontal and vertical components of tilted E field through a wide frequency band. Therefore, the cross polarization ratio of a dipole square dramatically degrades at edges of +/- 60 degree sector at the highest operating frequency.

To overcome this disadvantage, many other dual polarized radiators having smaller dimensions were invented. Crossed dipoles having different kinds of dipole arms are described in US6933906B2, US7132995B2, US2012/0235873 A1, CN102074779A, CN102157783A, CN101707291A, CN101572346A, CN201741796U, CN101546863A, CN101673881A, CN202150554U, CN102246352A, CN102484321A, CN202423541U, CN102544764A and CN101707287A. At the H plane, a beam of crossed dipoles is too wide. Therefore, big side walls are used to reduce a beam width as shown, for example, in US7679576B2.

Crossed dipoles containing different coupling elements between dipoles arms are described in CN201060942Y, CN201011672Y, CN202076403U, CN201243085Y and CN201898199U. These coupling elements create additional oscillating contours which increase operating frequency band of crossed dipoles but square shape of its radiating arrangements decreases cross polarization ratio at high frequencies. Such radiators are described in PCT/CN09/75661 and US2011/0291905 A1, and one such radiator is shown in Fig. 1 as the prior art. The known radiator 53 comprises two crossed dipoles containing four arms 54 and a connective portion 52 of a square shape connecting far corners of arms 54 with each other. Each arm 54 has a shape of a square frame and together with the connective portion 52, forms four oscillator arms 531-534 which form a radiating structure of a square shape (seen from a top view). Feeding terminals 5310-5340 are placed at corners facing another oscillator arm. In another variant of the known radiator, the connective portion has four parts of a shape of folded dipoles connected with two adjacent sides of two adjacent oscillator arms, respectively. Folded dipoles formed by a connective portion and connected to oscillator arms act as a dipole square, as described in WO 2007/114620A1.

Embodiments of the present invention seek to overcome deficiencies of the prior art and other known dual polarized antennas.

BRIEF DESCRIPTION OF PREFERRED EMBODIMENTS

According to an embodiment to the invention, there is provided a dual polarized antenna comprising: a radiating arrangement; and a feeding element containing two coaxial cables and two conductors forming two perpendicular baluns supporting the radiating arrangement above a reflective conductive plate. The radiating arrangement

5 comprises two crossed dipoles electrically connected by four outer conductors, the four outer conductors forming an outer contour of the radiating arrangement, the outer contour having a shape of a circle or a polygon; wherein each crossed dipole comprises two dipole arms, each dipole arm comprising two equal branches connected together at a point of connection between the dipole arm and outer

10 conductor of one coaxial cable; wherein a first gap between the two equal branches of each dipole arm, and a second gap between adjacent branches of different dipole arms, increases towards the outer contour of the radiating arrangement; wherein each outer conductor has a middle portion and two end portions, the middle portion connecting adjacent branches of different dipole arms with the two end portions,

15 wherein one end portion is placed between the branches of one dipole arm and the other end portion is placed between the branches of an adjacent dipole arm; and wherein one end portion of one outer conductor and the other end portion of an adjacent outer conductor are placed between the two branches of one of the dipole arms, and are separated from each other by a third gap creating a capacitive

20 coupling between the two outer conductors.

Each end portion of each outer conductor may have a projection placed on a bottom surface of the radiating arrangement and directed towards the reflective ground plate.

25 Each dipole arm of the radiating arrangement contains the third short branch placed between the two equal branches and connected to the point of connection branches to an outer conductor of a coaxial cable. A length of the third branch may be two or more times shorter than a length of equal branches.

30 The radiating arrangement may be formed from a single sheet of conductive material.

The radiating arrangement and the feeding element may be made as one part by die-casting.

35 The radiating arrangement may be a printed circuit board.

The feeding element may be connected to the dipole arms in the middle of the radiating arrangement and may comprise four tubes containing two coaxial cables inside and connected by a flat conductor nearby the reflective conductive plate.

- 5 The inner conductors of the coaxial cables are directly connected to conductive bridges. The conductive bridges may be directly connected to the radiating arrangement. The conductive bridges may be connected to open stubs placed inside of the tubes and creating capacitive coupling between the coaxial cables and the radiating arrangement.

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The dual polarized antenna may further comprise a thin dielectric film placed between the feeding element and the reflecting conductive plate. The reflective conductive plate may have at least two side walls.

- 15 Several radiating arrangements with the feeding elements may be placed above the reflective conductive plate to form an antenna array.

A maximum dimension of the radiating arrangement may be smaller than 0.6 wave length corresponding to a middle operating frequency. A distance between the
20 radiating arrangement and the reflective conductive plate may be smaller than 0.25 wave length corresponding to a middle operating frequency.

Embodiments of the present invention seek to provide a dual-polarized antenna providing 60-65 degree half power beam width and a cross polarization ratio better
25 than -10 dB at edges of +/- 60degree sector through at least 46% of a frequency band. Embodiments of the present invention also seek to improve matching of a dual-polarized antenna operating through a wide frequency band. Embodiments of the present invention further seek to create a wide band antenna which is easy to be manufactured.

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BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute part of the specification, illustrate embodiments of the invention and, together with the general
35 description of the invention given below, serve to explain the principles of the invention.

In the accompanying drawings:

Fig. 1 is a dual polarized radiating element from the prior art (PCT/CN09/75661, US2011/0291905A1), wherein four square arms are connected by connective portions to form four oscillator arms, which form a radiating structure of a square shape in a top view.

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Fig. 2a is a top view of a radiating arrangement according to an embodiment of the invention.

Figs. 2b and 2c show voltages and currents on the radiating arrangement shown in

10 Fig. 2a, radiating a vertical and horizontal E field, respectively.

Fig. 3 illustrates a functional circuitry of one-half of the radiating arrangement shown in Fig. 2a, and radiating vertical E field.

15 Fig. 4 is a simplified electrical circuit of the left part of the radiating arrangement radiating vertical E field as shown in Fig. 2a, wherein an electrical wall is placed at the horizontal axis of symmetry and a magnetic wall is placed at the vertical axis of symmetry.

20 Fig. 5 is a top view of another embodiment of the radiating arrangement, made as a printed board circuit placed on the surface of a dielectric substrate having the shape of an octagon.

25 Fig. 6 is a top view of another embodiment of the radiating arrangement made as a printed board circuit placed on the surface of a round dielectric substrate.

30 Fig. 7 is a perspective view of the dual polarized antenna wherein the radiating arrangement made as a printed board circuit of a round shape is supported above a square conductive plate by four metal tubes forming two perpendicular baluns and containing two coaxial cables inside.

35 Fig. 8a is a perspective view of the dual polarized antenna wherein the radiating arrangement is made as one conductive part having a round shape, supported above a square conductive plate by four metal tubes containing two feeding cables and two open stabs inside and connected to an additional conductive plate separated from the reflective plate by a dielectric plate.

Fig. 8b is the cross section of Fig. 8a through tubes containing feeding coaxial cable and a short cable with an open end creating capacitive coupling between the feeding coaxial cable and the radiating arrangement.

- 5 Fig.9 is a perspective view of a dual polarized antenna array containing four dual polarized antennas shown in Fig. 2a.

DETAILED DESCRIPTION

- 10 Fig. 2a is a top view of a radiating arrangement of a dual-polarized antenna, according to an embodiment of the invention. The radiating arrangement can be made as a simple planar structure from a thick conductive material. The radiating arrangement comprises two crossed dipoles. Each dipole comprises two dipole arms, wherein each dipole arm has two equal branches and a short branch connected at
15 feeding points 17-20. Feeding points 17-20 are disposed in the middle of the radiating arrangement.

- Four outer conductors 9-12 form the outer contour (or boundary or perimeter) of the radiating arrangement, and connect adjacent branches of dipole arms of crossed
20 dipoles. Each of these conductors 9-12 has two end portions and a middle portion, the middle portion connecting adjacent branches and two end portions. The first end portion is placed between branches of a vertical dipole's arm and the second end portion is placed between branches of a horizontal dipole's arm.

- 25 The distance between branches of a dipole arm increases towards the outer contour of the radiating arrangement. The distance between adjacent branches of crossed dipoles also increases towards the outer contour of the radiating arrangement. Adjacent end portions of conductors 9-12 placed between branches of a one arm are separated by gaps creating a capacitive coupling between these conductors. The
30 outer contour of the radiating arrangement formed by conductors 9-12 has a shape of a circle (or substantially circular, e.g. having discontinuities in the circumference of the circle).

- With reference to Fig. 2a, branches 1-2 and short branch 46 form the top arm of the
35 vertical dipole. Branches 3-4 and short branch 47 form its bottom arm. Branches 5-6 and short branch 48 form the left arm of the horizontal dipole. Branches 7-8 and short branch 4 form its right arm.

Conductor 9 connects branches 1 and 5 belonging to the vertical and horizontal dipoles respectively. The first end portion 1a of conductor 9 is placed between branches 1 and 2. The second end portion 5a of conductor 9 is placed between branches 5 and 6. Conductor 10 connects branches 2 and 7 belonging to vertical and horizontal dipoles respectively. The first end portion 2a of conductor 10 is placed between branches 1 and 2. The second end portion 7a of conductor 10 is placed between branches 7 and 8. Conductor 11 connects branches 4 and 8 belonging to vertical and horizontal dipoles respectively. The first end portion 4a of conductor 11 is placed between branches 3 and 4. The second end portion 8a of conductor 11 is placed between branches 7 and 8. Conductor 12 connects branches 3 and 6 belonging to vertical and horizontal dipoles respectively. The first end portion 3a of conductor 12 is placed between branches 3 and 4. The second end portion 6a of conductor 12 is placed between branches 5 and 6.

The end portion 1a of conductor 9 and the end portion 2a of conductor 10 are separated by gap 13. The end portion 7a of conductor 10 and the end portion 8a of conductor 11 are separated by gap 16. The end's portion 4a of conductor 11 and the end portion 3a of conductor 12 are separated by gap 14. The end portion 6a of conductor 12 and the end portion 5a of conductor 9 are separated by gap 15.

The short branch 46 placed between the main branches 1 and 2 is connected with ones at feeding point 17. The short branch 47 placed between the main branches 3 and 4 is connected with ones at feeding point 18. The short branch 48 placed between the main branches 5 and 6 is connected with ones at feeding point 19. The short branch 49 placed between the main branches 7 and 8 is connected with ones at feeding point 20.

A feeding element (not shown) is connected to the vertical dipole at points 17 and 18 and to the horizontal dipole at points 19 and 20.

The radiating arrangement has four axes of symmetry, shown as dashed lines in Fig. 2a. The first two axes of symmetry are places along the crossed dipoles. The other two axes of symmetry are placed between the crossed dipoles.

A feeding element (not shown) is connected to each dipole arm at the middle of the radiating arrangement and the bottom part of the feeding element is connected to a reflective conductive plate directly or by capacitive coupling. The feeding element can be made of tubes containing feeding cables inside. Another option is for the radiating

arrangement and the feeding element to be manufactured as a single part by die-casting.

The first feeding cable is connected between arms of the first dipole and the second
 5 feeding cable is connected between arms of the second dipole. The radiating
 arrangement excited in this way radiates two mutually perpendicular electrical fields
 having E vectors directed parallel to the dipoles axis as shown in Fig. 2b and Fig. 2c.
 The same situation applies for other embodiments of the radiating arrangements
 shown in Figures 5 to 10.

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The dual-polarized antenna according to embodiments of the invention contains
 three kinds of radiating elements. The first radiating element is the dipole arms
 containing long and short branches. The second radiating element is a cruciform slot
 formed by the branches of crossed dipoles and the middle parts of the outer
 15 conductors connecting these branches. The third radiating element is formed by two
 end portions of adjacent outer conductors and the two branches connected to them.
 Thus, the radiating arrangement according to embodiments of the invention is a small
 antenna array containing different radiating elements radiating at different
 frequencies.

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The dual-polarized antenna according to embodiments of the invention provides
 improved return loss or wider frequency band in comparison with conventional
 solutions, with the result that it is possible to change impedances and resonant
 frequencies of three kinds of radiating elements by changing its shape and match
 25 antenna with feeding cables through a wide frequency band.

The dual-polarized antenna according to embodiments of the invention also provides
 improved cross polarization ratio at edges of ± 60 degree sector in comparison with
 conventional solutions since dimensions of the radiating arrangement are less than
 30 dimensions of other antennas providing the same beam width in the H plane.

The dual-polarized antenna according to embodiments of the invention also provides
 less beam width in the H plane in comparison with conventional crossed dipoles
 since the crossed dipoles excited by the outer conductors creates additional radiation
 at low frequencies of operation frequency band.

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The dual-polarized antenna according to embodiments of the invention also provides
 more constant beam width in wide frequency band in comparison with conventional
 crossed dipoles since the short branches placed in the middle of the radiating

arrangement begin radiate at high frequencies of operation frequency band decreasing radiation from outer contour of radiating arrangement.

The dual-polarized antenna according to embodiments of the invention further provides less unwanted coupling between nearby radiators of antenna arrays having 60-70 degrees half power beam width in the horizontal plane in comparison with conventional dipole square, with the result that dimensions of the radiating arrangement are smaller. Therefore, the dual-polarized antennas according to embodiments of the invention are better suited for a design of modern base station antenna arrays having small distances between radiators to provide small upper side lobes in a vertical plane when a main beam is tilted up to 20 degrees.

Voltages and currents through the radiating arrangement excited via feeding points 17 and 18 and radiating vertical E field are shown in Fig.2b by solid arrows and dashed arrows respectively.

The currents distribution in Fig. 2b shows that the radiating arrangement contains several radiating elements. The first radiating element is the arms of the excited dipole formed by branches 1-4 and 46-47. The second radiating element is the cruciform slot 41 formed by the middle portions of conductors 9-12 and all eight branches connected to these middle portions of the conductors. As mentioned above, the distance between branches increases towards the outer contour of the radiating arrangement. Therefore each of the four parts of the cruciform slot acts as a radiating fin-line shorted by a conductor forming the outer contour of the radiating arrangement. The third radiating element 42 is formed by branches 5 and 6 of the crossed dipole and end portions 5a and 6a. The same radiating element 43 is formed by branches 7 and 8 of the crossed dipole and end portions 7a and 8a.

Voltages and currents through the radiating arrangement excited via feeding points 19 and 20 and radiating horizontal E field are shown in Fig.2c by solid arrows and dashed arrows respectively. The first radiating element is the arms of the excited dipole formed by branches 5-8 and 48-49. The second radiating element is the cruciform slot 41. The third radiating element 44 is formed by branches 1 and 2 of the crossed dipole and end portions 1a and 2a. The same radiating element 45 is formed by branches 3 and 4 of the crossed dipole and end portions 3a and 4a.

Thus the radiating arrangement acts as a small antenna array containing different radiating elements coupled with each other.

Fig. 3 illustrates a functional circuitry of one-half of the radiating arrangement radiating a vertical E field, wherein an electrical wall is placed at the horizontal axis of symmetry. A magnetic wall is placed at the vertical axis of symmetry. Since the left side of the radiating arrangement and the right side of the radiating arrangement are equal parts connected in a parallel circuit, it is possible to consider one quarter of the radiating arrangement only. Input impedances Z_{in} of the radiating arrangement between points 17 and 18 and its one quarter placed between the electrical wall and the magnetic wall are equal since two quarters are connected in parallel and in series with the other two quarters.

Fig.4 is the simplified equivalent electrical circuit of the top left part of the radiating arrangement excited via points 17 and 18 and radiating a vertical E field. Three kinds of radiating elements mentioned above are described by capacitors, inductors and resistors forming three oscillating contours connected with each other. Resistors describe radiation losses. Elements of this equivalent circuit are dependent on frequency; therefore, the circuit serves only to explain how the radiating arrangement operates and why the radiating arrangement provides good patterns and matching with feeding line through a wide frequency band.

Elements Ca, Ra and La form an equivalent circuit of short branch 46. Elements Cb, Rb, Lb₁ and Lb₂ form an equivalent circuit of branch 1 and end part 1a. Elements Cs, Rs, Lb₃ and Lb₄ form an equivalent circuit of branch 5 and end part 5a. These branches and end parts are equal but branch 1 is placed near magnetic wall and branch 5 is placed near electrical wall; therefore, their equivalent circuits have different elements.

Elements Cc, Rc and Lc form an equivalent circuit of the top left part of cruciform slot 41 formed by the middle portion of conductor 9 and branches 1 and 5. Conventional crossed dipoles formed by branches 1-8 provide approximately 65 degree beam width at E plane but a beam width at the H plane is wider. In both planes, a beam width decreases versus frequency. In the radiating arrangement, crossed dipoles are coupled to each other by conductors 9-12 in such a way that the horizontal dipole together with conductors 9 and 10 increases equivalent width and length of the vertical dipole. As the result, a low edge of an operating frequency band shifts to lower frequencies. The equivalent circuit of Fig. 4 shows this coupling by the oscillating contour Lb₄, Rs and Cs connected to Lb₁ by Lc. This oscillating contour has a resonance near a low edge of the operating frequency band; therefore a large

current flows through portion 5a. Radiation from portions 5a-8a placed at the left and right edges of the radiating arrangement decreases beam width in a horizontal plane and increase the gain of the antenna. Parallel oscillating contour Cc and Lc has a resonance at higher frequencies where the slot 41 radiates more efficiently. The oscillating contour Cb, Rb, Lb₁ and Lb₂ connected to other oscillating contours has a resonance near the high edge of the operating frequency band. Elements Ca, Ra and La form an equivalent circuit of short branch 46. This oscillating contour begins radiate at the high edge of the operating frequency band.

When the vertical dipole is excited, its short branches 46 and 47 radiate at high frequencies of an antenna's frequency band, providing radiating from the middle part of the arrangement to decrease a dependence of a beam width versus frequency and to improve matching with feeding lines. Short branches 48 and 49 of the horizontal dipole are placed on the electrical wall and therefore do not influence radiation.

Thus, radiating elements placed at an outer contour of the radiating arrangement mainly radiate at low frequencies of the operating frequency band and radiating elements placed at the middle mainly radiate at high frequencies.

A beam width of the dual-polarized antenna according to embodiments of the invention has less dependence versus frequency in comparison with conventional solutions, with the result that its outer contour radiates at low frequencies of operating frequency band and its inner portions radiate at high frequencies.

The dual-polarized antenna according to embodiments of the invention provides improved cross polarization ratio at the edges of ± 60 degree sector in comparison with conventional solutions, with the result that a round shape of the radiating arrangement decreases its size in the E plane, providing less difference between its patterns in orthogonal planes.

The dual-polarized antenna according to embodiments of the invention provides improved return loss or wider frequency band in comparison with conventional solutions, with the result that embodiments of the invention contain several kinds of radiating elements having resonances at different frequencies.

Inventive step of this invention consist of creation multiple-resonant-mode dual polarized antenna with a single radiating pattern formed by conductors connected in the new way. Each quarter of a single radiating pattern comprising one feeding point contains three points where three conductors jointed together. Two equal long

branches connected with a short branch at feeding point. Each of long branches connected with outer conductor dividing one on middle portion and end portion.

Several exemplary embodiments of the dual-polarized antenna according to other
5 embodiments of the invention are described below with the aid of Fig. 5 to Fig. 9.

Fig. 5 is a top view of another embodiment of the radiating arrangement placed on a surface of a dielectric substrate 55 having the shape of an octagon. The width of branches 21-28 decreases, and the distances between these branches increases,
10 towards the outer contour of the radiating arrangement. Conductors 29-32 form the outer contour of an octagon. The middle parts of the conductors 29-32 are narrow and the end portions 21a-28a are wide (relative to the middle parts) to create sufficient coupling between thin conductors printed on the surface of the dielectric substrate 55. Feeding lines are connected to the vertical dipole at points 37 and 38
15 and to the horizontal dipole at points 39 and 40. Short branches 33-36 are connected with branches 21-28 at points 37-39 respectively.

Fig. 6 is a top view of another embodiment of the radiating arrangement placed on a surface of a round dielectric substrate 56. The width of branches 71-78 decreases,
20 and distances between these branches increases, towards the outer contour of the radiating arrangement. Conductors 79-82 form the outer contour, which conforms to the circumference of the round dielectric substrate 56. Middle parts of the conductors 79-82 are narrow and the end portions 71a-78a are wide (relative to the middle parts) to create sufficient coupling between thin conductors printed on the surface of a
25 dielectric substrate 56. Feeding lines are connected to the vertical dipole at points 87 and 88 and to the horizontal dipole at points 89 and 90. Short branches 83-86 are connected with branches 71-78 at points 87-89 respectively.

30 Different embodiments of the radiating arrangement shown on Figs. 2, 5 and 6 contain many different conductors. Therefore, it is possible to tune patterns of the radiating arrangement in both planes and match one with feeding cables through a wide frequency band by adjusting dimensions of these conductors.

Fig. 7 is a perspective view of a dual polarized antenna according to an embodiment
35 of the invention shown in Fig. 6, wherein the radiating arrangement is made using the printed board circuit 57 placed on a substrate 56 having a round shape. The radiating arrangement is supported above the square conductive plate 58 by four metal tubes 59-62 forming a balun. The top ends of these tubes are connected to feeding points

of the radiating arrangement and its bottom ends are connected to the conductive plate 58. Feeding coaxial cables are placed inside of tubes 59 and 61. Inner conductors of these cables are connected to the conductive bridges 63 and 64. Other ends of these bridges are directly connected to opposite feeding points. The dual polarized antenna shown in Fig. 8 radiates two mutually perpendicular electrical fields having E vectors directed parallel to sides of the square conductive plate 58.

Fig. 8a is a schematic view of a dual polarized antenna according to another embodiment of the invention, wherein the radiating arrangement 65 is made using one conductive part having a round shape. The ends of conductors have projections 101-108 placed opposite each other on the bottom surface of the radiating arrangement. These projections increase coupling between adjacent conductors and at the same time create currents directed towards the reflecting conductive plate 66. Radiation created by these currents directed parallel the reflecting conductive plate 66 changes a shape of E plane patterns to increase beam width at high frequencies and improve cross polarization ratio at the edges of ± 60 degree sector.

The radiating arrangement 65 is supported above the square conductive plate 66 by four metal tubes 67-70 forming two perpendicular baluns. The top ends of these tubes are connected to feeding points of the radiating arrangement 65. The bottom ends are connected to the flat conductor plate 97 and are separated from the plate 66 by the dielectric plate 98 to minimize passive intermodulation products from being generated by metal to metal connection.

Feeding coaxial cables are placed inside tubes 67 and 69. Inner conductors 91 and 92 of the feeding coaxial cables are connected to conductive bridges 93 and 94 respectively. Other ends of the bridges are connected to inner conductors 95 and 96 of short coaxial cables placed inside tubes 68 and 70 respectively. The dual polarized antenna shown on Fig. 8a radiates two mutually perpendicular electrical fields having E vectors directed along diagonals of the square conductive plate 66.

The cross section through tubes 67 and 68 is shown on Fig. 8b. The bottom end of conductor 95 is open; therefore conductor 95 creates capacitive coupling between a feeding line and the radiating arrangement. Therefore, it is no need to solder the conductive bridges to the thick radiating arrangement. The absence of a direct contact between these parts simplifies antenna assembly and minimizes of opportunity for passive intermodulation products from being generated by soldering of the conductive bridges to the thick metal part.

Fig. 9 is a perspective view of a dual polarized antenna array containing four antennas having the radiating arrangement shown on Fig. 2a. The array radiates two mutually perpendicular electrical fields having E vectors directed at +45 and -45 degree from the long side of rectangular conductive plate 99 containing side walls 109. A small size of the radiating arrangement decreases unwanted coupling between neighboring antennas, improving isolation between outputs of the antenna array.

Several samples of the dual polarized antenna having 60-66 degree half power beam width were designed according to embodiments of the invention to operate in the 1710 to 2690 MHz frequency band. Isolation between polarizations was more than 34 dB and VSWR better than 1.25 for all samples. A sample of a +/-45 degree slant polarization antenna array containing four antennas has Isolation better than 30 dB between polarizations in the 1710 to 2690 MHz frequency band and VSWR better than 1.2. A cross polarization ratio of this antenna array is -22 dB at the main direction and -10 dB at the edges of +/-60 degree sector.

The radiating arrangement has a simple planar shape providing repeatable Isolation and VSWR of antennas from a product line; therefore, antennas according to embodiments of the invention are suitable for the design of antennas operating at higher frequencies (for example 3300-5800MHz).

While the present invention has been illustrated by the description of the embodiments thereof, and while the embodiments have been described in detail, it is not the intention of the Applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative devices and illustrative examples shown and described. Accordingly, departures may be made from such details without departure from the spirit or scope of the Applicant's general inventive concept.

CLAIMS

1. A dual polarized antenna comprising:

a radiating arrangement; and

5 the feeding element containing two coaxial cables and two conductors forming two perpendicular baluns supporting the radiating arrangement above a reflective conductive plate;

10 wherein the radiating arrangement comprises two crossed dipoles electrically connected by four outer conductors, the four outer conductors forming an outer contour of the radiating arrangement, the outer contour having a shape of a circle or a polygon;

wherein each crossed dipole comprises two dipole arms, each dipole arm comprising two equal branches connected together at a point of connection between the dipole arm and outer conductor of one of the two coaxial cables;

15 wherein each dipole arm of the radiating arrangement contains the third branch placed between two equal branches and connected to the point of connection the dipole arm and outer conductor of one of the two coaxial cables;

20 wherein the first gap between two equal branches of each dipole arm, and the second gap between adjacent branches of different dipole arms increase towards the outer contour of the radiating arrangement;

25 wherein each outer conductor has a middle portion and two end portions, the middle portion connecting adjacent branches of different dipole arms with the two end portions, wherein one end portion is placed between the branches of one dipole arm and the other end portion is placed between the branches of an adjacent dipole arm; and

30 wherein one end portion of one outer conductor and the other end portion of an adjacent outer conductor are placed between the two branches of one of the dipole arms, and are separated from each other by a third gap creating a capacitive coupling between the two outer conductors.

2. A dual polarized antenna according to claim 1, wherein each end portion of each outer conductor has a projection placed on a bottom surface of the radiating arrangement and directed towards the reflective ground plate.

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3. A dual polarized antenna according to any preceding claim, wherein a length of the third branch is at least two times shorter than a length of equal branches.

4. A dual polarized antenna according to any preceding claim, wherein the radiating arrangement is formed from a single sheet of conductive material.
- 5 5. A dual polarized antenna according to any preceding claim, wherein the radiating arrangement and the feeding element are made as one part by die-casting.
6. A dual polarized antenna according to any preceding claim, wherein the
10 radiating arrangement is a printed circuit board.
7. A dual polarized antenna according to any preceding claim, wherein the feeding element is connected to the dipole arms in the middle of the radiating arrangement and comprises four tubes containing two inner conductors of
15 coaxial cables inside and connected by a flat conductor nearby the reflective conductive plate.
8. A dual polarized antenna according to claim 7, wherein inner conductors of the coaxial cables are directly connected to conductive bridges.
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9. A dual polarized antenna according to claim 7 and 8, wherein conductive bridges are directly connected to the radiating arrangement.
10. A dual polarized antenna according to claim 7 and 8, conductive bridges
25 connected to open stubs placed inside of the tubes and creating capacitive coupling between the coaxial cables and the radiating arrangement.
11. A dual polarized antenna according to any preceding claim, further comprising a thin dielectric film placed between the feeding element and the
30 reflecting conductive plate.
12. A dual polarized antenna according to any preceding claim, wherein the reflective conductive plate has at least two side walls.
- 35 13. A dual polarized antenna according to any preceding claim, wherein two or more radiating arrangements and corresponding feeding elements are placed above the reflective conductive plate to form an antenna array.

14. A dual polarized antenna according to any preceding claim, wherein a maximum dimension of the radiating arrangement is smaller than 0.6 wave length corresponding to a middle operating frequency.

5 15. A dual polarized antenna according to any preceding claim, wherein a distance between the radiating arrangement and the reflective conductive plate is smaller than 0.25 wave length corresponding to a middle operating frequency.