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

(11) EP 2 950 385 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
24.08.2016 Bulletin 2016/34

(51) Int Cl.:
H01Q 5/40 *(2015.01)* ***H01Q 9/42*** *(2006.01)*
H01Q 21/26 *(2006.01)* ***H01Q 1/24*** *(2006.01)*

(21) Application number: **14305798.2**

(22) Date of filing: **28.05.2014**

(54) **Multiband antenna**

Mehrbandantenne

Antenne multibande

(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

(43) Date of publication of application:
02.12.2015 Bulletin 2015/49

(73) Proprietor: **Alcatel Lucent**
92100 Boulogne-Billancourt (FR)

(72) Inventor: **Kokkinos, Titos**
70435 Stuttgart (DE)

(74) Representative: **Knecht, Ulrich Karl et al**
Alcatel Lucent
Intellectual Property & Standards
70430 Stuttgart (DE)

(56) References cited:
EP-A1- 1 487 051 **WO-A1-02/07254**
WO-A1-2008/009667 **US-A1- 2006 145 926**
US-A1- 2009 278 759 **US-A1- 2012 038 533**
US-A1- 2012 146 854 **US-A1- 2012 274 532**
US-A1- 2012 319 919

EP 2 950 385 B1

Description

[0001] Embodiments of the present disclosure relate to antennas and, more particularly, to multiband antennas for mobile communications applications.

Background

[0002] This section introduces aspects that may be helpful in facilitating a better understanding of the embodiments of the present disclosure. Accordingly, the statements of this section are to be read in this light and are not to be understood as admissions about what is in the prior art or what is not in the prior art.

[0003] A vast majority of modem mobile cellular communications/services are offered across two main frequency regions of the licensed frequency spectrum.

[0004] In various examples, a first of these regions extends from 690 MHz to 960 MHz, i.e., it may be composed of frequencies smaller than 1 GHz. The fractional bandwidth of this frequency region may approximately be 35%. This means that the bandwidth of the frequency region corresponds to 35% of its center frequency. For the needs of this disclosure, this first frequency region will be referred to as 'low-frequency-region'. The standardized 3rd Generation Partnership Project (3GPP) frequency bands of the 'low-frequency-region' are used worldwide to support all the popular cellular technologies (2nd Generation (2G), 3rd Generation (3G) and 4th Generation (4G)) and are considered particularly suitable for enabling mobile coverage in large geographical areas due to their relatively large wavelengths and, hence, the lower propagation losses they undergo per unit of physical distance.

[0005] In various further examples, a second frequency region across which cellular communication services are offered worldwide extends from 1710 MHz to 2690MHz (fractional bandwidth: ~45%). For the needs of this disclosure, this second frequency region will be referred to as 'high-frequency region'. Similarly with the 'low-frequency region', conventional antenna technology includes patch or dipole radiators and arrays of them, fed against ground planes, which are capable of supporting parts or the complete 'high-frequency- region'. For the mentioned example high-frequency region the minimum size of such radiators would be 9 cm x 9 cm (footprint) x 3.5 cm (profile) - also dictated by the wavelength at the center frequency of the frequency region.

[0006] Due to the increased demand for cellular wireless services, nowadays multiple frequency bands across both the above frequency regions are simultaneously used in the same geographical regions. In order to reduce the visual impact of such coexisting networks, Mobile Network Operators (MNOs) choose to deploy such networks using a single and common antenna panel per base station. In order for such deployments to be achieved, antennas and antenna arrays (panels) capable of supporting simultaneously both the 'low-frequency region' and the 'high-frequency region' are desired.

[0007] An efficient way for designing such multiband antennas is by combining 'low-frequency region' radiators (dipole-squares) and 'high-frequency region' radiators (dipoles) in the same physical volume. For example, this may be achieved by integrating the 'high-frequency region' radiator in the center of the square dipole ('low-frequency region') radiator. The physical size of such a multiband radiator is dictated by the size of the larger of the two individual radiators, hence the 'low-frequency region' radiator. This implies that the minimum possible size for such a radiator would be approximately 17.5 cm x 17.5 cm (footprint) x 9 cm (profile) for the above examples.

[0008] A conventional multiband antenna with a dipole antenna structure and an inverted-F antenna structure is known from EP 1 487 051 A1. Further conventional antennas are known from US 2009/0278759 A1, WO 2008/009667 A1, US 2012/0319919 A1, US 2012/0038533 A1 and WO 02/07254 A1, or US 2012/274532 A1.

[0009] Nevertheless, such a radiator may be considered too bulky for applications in which the antenna is integrated with further parts of the radio, and where the complete unit (e.g., antenna + filter + RF transceiver) has to be as small as possible for a possibly minimum visual impact.

Summary

[0010] Some simplifications may be made in the following summary, which is intended to highlight and introduce some aspects of the various example embodiments, but such simplifications are not intended to limit the scope of embodiments. Detailed descriptions of a preferred exemplary embodiment adequate to allow those of ordinary skill in the art to make and use the inventive concepts will follow in later sections.

[0011] According to a first aspect of the present disclosure, it is provided a multiband antenna, according to claim 1.

[0012] The inverted-F antenna structure may include a first pair of differentially feedable inverted-F antenna elements and a second pair of differentially feedable inverted-F antenna elements.

[0013] In some embodiments, the dipole antenna structure may be configured to radiate electromagnetic waves in at least two polarizations and may comprise, per polarization, a first and a second dipole antenna part arranged point symmetrically with respect to a symmetry center of the dipole antenna structure. The first and the second dipole antenna part (per polarization) together form a dipole antenna (per polarization).

[0014] In some embodiments, the inverted-F antenna structure may be configured to radiate electromagnetic waves in at least two polarizations and may comprises, per polarization, a pair of inverted-F antenna elements. A first and a second inverted-F antenna element of a pair may be arranged point symmetrically with respect to a symmetry center of the inverted-F antenna structure.

[0015] In some embodiments, the first and the second inverted-F antenna element of a first polarization may be arranged at first diagonally opposing corner regions of the ground plane and the first and the second inverted-F antenna element of a second polarization may be arranged at second diagonally opposing corner regions of the ground plane.

[0016] In some embodiments, the inverted-F antenna structure may comprise four inverted-F antenna elements, wherein each inverted-F antenna element is arranged at a different corner of a square area spanned by the four inverted-F antenna elements.

[0017] In some embodiments, the first and the second inverted-F antenna elements corresponding to the same polarization may be coupled to an antenna port via a power divider. Electrical lengths of lines between the power divider and respective feedings points associated to the first and the second inverted-F antenna elements may differ by n*180°, n denoting an uneven integer.

[0018] In some embodiments, the inverted-F antenna structure may comprise a plurality of identically dimensioned inverted-F antenna elements. An inverted-F antenna element may comprise a first and a second passive arm coupled at right angles to each other and a fed arm coupled to the first and the second passive arm in a 45° angle, respectively.

[0019] In one embodiment, the fed arm and the first and the second passive arms may be arranged co-planar in parallel to the ground plane.

[0020] In one embodiment, the fed arm and the first and the second passive arm may join in a corner region of the inverted-F antenna element.

[0021] In one embodiment, the corner region of the inverted-F antenna element may be coupled to a corner region of the ground plane via a vertically extending grounding post.

[0022] In one embodiment, a main axis of the fed arm may point to the dipole antenna structure and/or a symmetry center of the inverted-F antenna structure.

[0023] In one embodiment, the fed arm of the inverted-F antenna element may be coupled to an associated feeding pin of the inverted-F antenna structure.

[0024] In one embodiment, a main axis of the first passive arm may extend in parallel to a first side of the ground plane. A main axis of the second passive arm may extend in parallel to a second side of the ground plane, the second side being rectangular to the first side.

[0025] In one embodiment, the fed arm may be split at its inner end facing the dipole antenna structure and/or a symmetry center of the inverted-F antenna structure into a first and a second fed arm portion. The first fed arm portion may extend in parallel to the first passive arm. The second fed arm portion may extend in parallel to the second passive arm.

[0026] In some embodiments, a feeding network of the inverted-F antenna structure may comprise band stop elements configured to decouple the dipole antenna structure from the inverted-F antenna structure. In some embodiments, a band stop element may comprise an open stub between an antenna port for the inverted-F antenna structure and a power divider of the feeding network. A length of the open stub may substantially correspond to a quarter wavelength of a center frequency of the second frequency band.

[0027] In some embodiments, the ground plane, dipole antenna structure, and the inverted-F antenna structure may be electrically conductive.

[0028] In some embodiments, the ground plane may be implemented on a plated surface of a printed circuit board.

[0029] Embodiments propose a compact, dual-linearly polarized, directional, multiband, and wideband radiator. Such a radiator may be particularly suitable for small-cell applications in which visual impact is critical for the success of a product, and in which some degradation of the antenna performance might be acceptable for most of the deployment and coverage scenarios.

[0030] Embodiments propose an antenna design concept with a small form factor for compact multiband antennas. Such an antenna may be the enabling technology for compact and multiband small cells with integrated atnennas, for example. In the context of Long-Term Evolution (LTE) and LTE-Advanced (LTE-A) including MIMO, Beamforming, Carrier Aggregation technologies etc., such small cells could play a critical role for deliveling the required coverage and throught to the end user.

Brief description of the Figures

[0031] Some example embodiments of apparatuses and/or methods will be described in the following by way of example only, and with reference to the accompanying figures, in which

Fig. 1 illustrates a top-view of a 'low-frequency-region' dipole-square configuration, in which wire-dipoles are located at four edges of a square constellation;

Fig. 2 illustrates a top-view of a further 'low-frequency-region' dipole-square configuration, in which wire-dipoles are located at four corners of the square constellation;

Fig. 3 illustrates a top-view of a multiband radiator, wherein a 'high-frequencyregion' dipole is integrated in the center of a 'low-frequency-region' dipole-square;

Fig. 4 shows a perspective view of a multiband antenna according to an embodiment;

Fig. 5 shows the top-view of the embodiment of Fig. 4;

Fig. 6 illustrates an embodiment of a feeding network of a multiband antenna;

Fig. 7 shows a perspective view of an alternative implementation of a multiband antenna;

Fig. 8 shows a perspective view of a further embodiment of the multiband antenna; and

Fig. 9 shows a perspective view of yet a further embodiment of the multiband antenna.

Description of Embodiments

[0032] Various example embodiments will now be described more fully with reference to the accompanying drawings in which some example embodiments are illustrated.

[0033] Accordingly, while example embodiments are capable of various modifications and alternative forms, embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that there is no intent to limit example embodiments to the particular forms disclosed, but on the contrary, example embodiments are to cover all modifications, equivalents, and alternatives falling within the scope of the claims. Like numbers refer to like elements throughout the description of the figures. It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element, without departing from the scope of example embodiments. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0034] It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g.., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.).

[0035] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes" and/ or "including," when used herein, specify the presence of stated features, integers, steps, operations, elements and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components and/ or group thereof.

[0036] It should also be noted that in some alternative implementations, the functions/ acts noted may occur out of the order noted in the figures. For example, two figures shown in succession may in fact be executed substantially concurrently or may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

[0037] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which example embodiments belong. It will be further understood that terms, e.g., those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0038] Today, a vast majority of modem mobile cellular communications/services are offered across two main frequency regions of the licensed frequency spectrum. A first of these regions extends from 690 MHz to 960 MHz, i.e., it is composed of frequencies smaller than 1 GHz. The fractional bandwidth of the example frequency region is approximately 35%. For the needs of the present disclosure, this frequency region will be referred to as 'low-frequency-region'. The skilled person will however appreciate that other nominal frequency regions than the mentioned example may be used as well without departing from the scope of the present invention.

[0039] The standardized 3GPP frequency bands of the 'low-frequency-region' are used worldwide to support all the popular cellular technologies (2G, 3G and 4G) and are considered particularly suitable for enabling mobile coverage in large geographical areas due to their relatively large wavelengths and, hence, the lower propagation losses they undergo per unit of physical distance.

[0040] From an antenna technology point of view, parts or the entire 'low-frequency-region' can be supported by various types of dual-linearly polarized, directional antenna elements, such as patch, dipole and dipole-square radiators (fed against a ground plane) and arrays of them (antenna panels). The latter type among these antennas (dipole-square) is the most commonly used as it exhibits several comparative advantages, e.g. larger bandwidth, higher directivity, lower tracking, etc. The dipole-square is composed of four wire-dipoles (two per polarization) arranged in a square configuration and fed in pairs; co-polarized dipoles are fed from a single port through some kind of corporate feeding network.

[0041] The top-view of an example dipole-square configuration 10 is shown in **Fig. 1**. Four wire-dipoles 11-1, 11-2, 11-3, and 11-4 are located on four edges of a square. These four wire-dipoles 11-1, 11-2, 11-3, and 11-4 are installed and fed approximately $\lambda/4$ above a RF (Radio Frequency) ground plane 13 by means of a mounting structure and a corporate feeding network 12. The wire-dipoles 11-1, 11-2, 11-3, and 11-4 extend in parallel to the RF ground plane 13 and its four edges. The dipoles 11-1 and 11-2 form a first pair corresponding to a first polarization, while the dipoles 11-3 and 11-4 (being perpendicular to the dipoles 11-1 and 11-2) form a second pair corresponding to a second polarization. For this configuration 10, the parallel wire-dipoles of a pair are fed in-phase from the same antenna port through either a cable-based or a circuit-based corporate feeding network. The respective co-polarized dipoles 11-1, 11-2 and 11-3, 11-4 are fed from a respective port through the corporate feeding network having feed lines 12.

[0042] In the top-view of **Fig. 2** another example of a dipole-square 20 is depicted. For this example implementation, four wire dipoles 21-1, 21-2, 21-3, and 21-4 have been located at the four corners of the square constellation, respectively. The four wire-dipoles 21-1, 21-2, 21-3, and 21-4 are installed and fed approximately $\lambda/4$ above the RF ground plane 13 by means of the mounting structure and the corporate feeding network 12. The wire-dipoles 21-1, 21-2, 21-3, and 21-4 extend in parallel to the RF ground plane 13. They differ from the dipoles 11-1, 11-2, 11-3, and 11-4 of Fig. 1 in that the two $\lambda/4$ rod elements 21a, 21b of a dipole 21 are perpendicular to each other. In Fig. 1, the two $\lambda/4$ rod elements coupled to feed line 12 extend co-linear. In Fig. 2, the dipoles 21-1 and 21-2 form a first pair corresponding to a first polarization, while the dipoles 21-3 and 21-4 form a second pair corresponding to a second polarization. For the configuration 20, the wire-dipoles corresponding to a pair are fed in-phase from the same antenna port through either a cable-based or a circuit-based corporate feeding network.

[0043] The minimum plausible electrical size of such an antenna 10, 20 dictated by the wavelength λ in the mid of its operating frequency band would be approximately $\lambda/2 \times \lambda/2 \times \lambda/4$ (footprint x profile). For the example of 825 MHz (roughly the mid of the 'low-frequency-region') the wavelength is approximately 35 cm, and, hence, the minimum size of the conventional antenna 20 would be 17.5 cm x 17.5 cm (footprint) x 8.5 cm (profile). Such a radiator would provide directivity or gain values in the range of 5-6 dBi. Note that antenna gain is usually defined as the ratio of the power produced by the antenna from a far-field source on the antenna's beam axis to the power produced by a hypothetical lossless isotropic antenna, which is equally sensitive to signals from all directions. Usually this ratio is expressed in decibels, and these units are referred to as "decibels-isotropic" (dBi). In order to further increase the directivity, larger ground plane sizes (footprint) could be considered.

[0044] A second example frequency region across which cellular communication services are offered worldwide extends from 1710 MHz to 2690MHz (fractional width: ~45%). For the needs of the present disclosure, this frequency region will be referred to as 'high-frequency region'. Again the skilled person will appreciate that other nominal frequency regions than the mentioned example may be used as well without departing from the scope of the present invention. Similarly with the 'low-frequency region', conventional antenna technology includes patch or dipole radiators and arrays of them, fed against ground planes, which are capable of supporting parts or the complete 'high-frequency-region'. For the example high-frequency region the minimum size of such radiators would be 9 cm x 9 cm (footprint) x 3.5 cm (profile) - also dictated by the wavelength at the mid-frequency.

[0045] Due to the increased demand for cellular wireless services, nowadays multiple frequency bands across both the above example frequency regions are simultaneously used in the same geographical regions. In order to reduce the visual impact of such coexisting networks, MNOs choose to deploy such networks using a single and common antenna panel per base station. In order for such deployments to be achieved, antennas and antenna arrays (panels) capable of supporting simultaneously both the 'low-frequency region' and the 'high-frequency region' are required.

[0046] One efficient way for designing such antennas is by combining 'low-frequency region' radiators (e.g. dipole-squares) and 'high-frequency region' radiators (e.g. dipoles) in the same physical volume or housing. This is usually achieved by integrating the 'high-frequency region' radiator in the center of the square dipole ('low-frequency region') radiator. Such an example multiband radiator 30 is shown in **Fig. 3**, where a 'high-frequency region' dipole 32 has been placed in the middle or center of an outer 'low-frequency region' dipole-square 31. In this example, the 'high-frequency region' dipole structure 32 is implemented by two pairs of differentially fed square dipole parts 32-1, 32-2 and 32-3, 32-4. That is to say, a first polarization is implemented by a first pair of diagonally opposing dipole parts 32-1, 32-2, while a second polarization is implemented by a second pair of opposing dipole parts 32-3, 32-4. Edges of the dipole parts 32-1, 32-2, 32-3, 32-4 have length of substantially a quarter wavelength. The physical size of such a multiband radiator 30 is dictated by the size of the larger of the two individual radiators, hence the 'low-frequency region' radiator 31. This implies that the minimum possible size for such a radiator would be approximately 17.5 cm x 17.5 cm (footprint) x 9 cm (profile) for the given example. Nevertheless, such a radiator is considered too bulky for small cell applications in which the antenna in integrated with remaining of the radio, and the complete unit (antenna + filter + RF transceiver) has to be as small (minimum visual impact) as possible.

[0047] In the following, various embodiments of a new type of a compact, dual-linearly polarized (slant $\pm 45°$), directional, multiband and wideband radiator are proposed. Similarly with conventional multiband antennas, embodiments of the multiband antenna are composed of a 'low-frequency region' radiator coexisting in the same physical volume or housing with a 'high-frequency region' radiator. For the 'low-frequency region' radiator, some embodiments suggest to swap the conventional dipole-square with a so-called 'IFA-square' (IFA = Inverted F-Antenna), namely a configuration of four inverted-F antenna elements located at the four corners of a square area.

[0048] In its most basic form, an inverted-F antenna (IFA) is a quarter wave long conductor parallel to and within a few mm of the RF ground plane, grounded at one end, and has a 50 Ohm feedpoint close to the grounded end. The quarter wave conductor can be a thin wire, a trace on a Printed Circuit Board (PCB), hence a 2-Dimensional (2D) structure, or a 3-Dimensional (3D) surface and can be straight or folded into complex shapes. Although the present specification uses the general term IFA, embodiments include both 2D and 3D IFA structures.

[0049] In some embodiments, the employed inverted-F antenna elements are not conventional IFAs, but have been designed to be multi-arm structures, providing larger flexibility in the range of real and imaginary impedances at which they can be tuned to operate. Finally, in the middle or center of this outer 'low-frequency region' IFA-square structure, the inner 'high-frequency region' radiator may be located. The 'high-frequency region' radiator may be implemented using any of the well-known types of dipole radiators that can deliver a required performance.

[0050] One major advantage of embodiments of the proposed multiband antenna is that the use of IFA elements instead of dipole elements for the outer square configuration ('low-frequency region' radiator) may allow for significant reduction of the height of the 'low-frequency region' radiator. As it has been already discussed, in the conventional dipole-square, the height or profile of the radiator is dictated by the wavelength in the middle of the operating band. Specifically, this height has to be approximately equal with a quarter of the wavelength (e.g., ~8.5cm at 825 MHz) so as the dipoles that comprise the dipole-square configuration to exhibit the required resistance and can be matched to the standard 50 Ohm impedance level. Nevertheless, with the use of the proposed IFA elements for the outer square-configuration, the matching of the resulting structure becomes somewhat independent of its height.

[0051] One example embodiment of the proposed compact and multiband antenna 400 is depicted in **Fig. 4**.

[0052] The multiband antenna 400 includes a horizontally extending ground plane 49. A dipole antenna structure 46 of the multiband antenna 400 is coupled to the ground plane 49 and is configured to radiate electromagnetic waves in a first frequency band, for example in the 'high-frequency-region'. The multiband antenna 400 also includes an inverted-F antenna (IFA) structure 40 comprising at least two pairs of IFA elements 40-1, 40-2, 40-3, 40-4 which are coupled to the ground plane 49. The IFA structure 40 is configured to radiate electromagnetic waves in a second frequency band, for example in the 'low-frequency-region. That is to say, the frequencies of the first frequency band may be higher than the frequencies of the second frequency band. In some embodiments, the first frequency band may lie in the region from 1710 MHz to 2690MHz; the second frequency band may lie in the region from 690 MHz to 960 MHz.

[0053] In the example embodiment of Fig. 4 the dipole antenna structure 46 and the IFA structure 40 comprising the four IFA elements 40-1, 40-2, 40-3, 40-4 are arranged concentrically on the common RF ground plane 49, which may be of square shape. The inner dipole antenna structure 46 is encompassed or surrounded by the IFA elements of the outer IFA structure 40.

[0054] In the example embodiment of Fig. 4, the dipole antenna structure 46 is configured to radiate electromagnetic waves in two perpendicular linear polarizations, for example 0°/90° or ±45°. It may comprise, per polarization, differentially fed first and second dipole antenna parts 46-1, 46-2 or 46-3, 46-4 (see top view in Fig. 5) arranged point symmetrically with respect to a symmetry center 44 of the dipole antenna structure 46 and/or the multiband antenna 400. A first pair of diagonally opposing dipole antenna parts 46-1, 46-2 implements a dipole antenna for a first polarization. A second pair of diagonally opposing dipole antenna parts 46-3, 46-4 implement a dipole antenna for a second polarization (perpendicular to the first polarization). The arms or rods of the dipole antenna parts may extend horizontally in parallel to the ground plane 49. In Fig. 4, a dipole antenna part 46-1, 46-2, 46-3, 46-4 of the dipole antenna structure 46 is formed by two perpendicular straight rods or arms, with a feedline connected to two adjacent ends of the rods forming a corner of the dipole antenna parts. The rods extend in parallel to the ground plane 49. The corners of the four dipole antenna parts all point towards the symmetry center 44.

[0055] The IFA structure 40 comprising the IFA elements 40-1, 40-2, 40-3, 40-4 is configured to radiate electromagnetic waves in two substantially perpendicular linear polarizations. It comprises, per polarization, a first and a second IFA element arranged point symmetrically with respect to the symmetry center 44. The first and the second IFA elements 40-1 and 40-2 of a first polarization (e.g. +45°) are arranged at first diagonally opposing corner regions 47 of the ground plane 49. The first and the second IFA elements 40-3 and 40-4 of a second polarization (e.g. -45°) are arranged at second diagonally opposing corner regions 47 of the ground plane 49. That is to say, the four IFA elements 40 that form the 'low-frequency-region' radiator are arranged on the four corners 47 of the antenna ground plane 49.

[0056] For the proposed antenna concept, the antenna ground plane 49 may be implemented on the plated surface of a Printed Circuit Board (PCB). The size of the ground plane 49, and hence the distance between the IFA elements 40, may be critical for the directivity performance of the proposed antenna 40. The same PCB may also be used in order to assemble the antenna parts together and form the complete multiband radiator.

[0057] The four IFA elements 40 of the IFA structure may be substantially identically dimensioned and structured, and may each comprise multiple arms 40a, 40b, 40c, respectively: one central fed (or feed) arm 42 and two passive arms 43a and 43b. As can be seen from Fig. 4, the fed arm 42 and the first and the second passive arms 43a and 43b may be arranged co-planar in parallel to the ground plane 49. The two passive arms 43a and 43b of an IFA element 40 may form a 90° corner. That is to say, according to some embodiments, an IFA element 40 may comprise a first and a second passive arm 43a and 43b coupled or joined at right angles to each other. The fed arm 42 may be coupled to or joined with the first and the second passive arms 43a and 43b in a 45° angle, respectively.

[0058] A main axis of the fed arm 42 may point to the dipole antenna structure 46 and/or the symmetry center 44. A main axis of the first passive arm 43a may extend in parallel to a first side or edge of the ground plane 49. A main axis of the second passive arm 43b may extend in parallel to a second side or edge of the ground plane 49, wherein the second side is perpendicular to the first side. The fed arm 42 and the first and the second passive arms 43a and 43b may join in a corner region 45 of the respective IFA element 40 corresponding to the arms 42, 43a, and 43b. At the corner 45 where the fed and the passive arms of the multi-arm IFA element are joined, there may also be a vertically oriented part 43 which operates as a grounding post of the IFA configuration. That is to say, the corner region 45 of the respective IFA element 40 may be coupled to a corner region 47 of the ground plane 49 via a vertically extending grounding post 43.

[0059] In the example implementation of Fig. 4, the four multi-arm IFA elements 40 are directly fed by feeding pins or lines 41 which are connected directly to the central arm 42 of the respective IFA element 40.

[0060] All the aforementioned parts, i.e. the ground plane 49, the dipole antenna structure 46, and the inverted-F antenna structure, should be conductive, and may be built either as a single mechanical part (molded or diecasted), or as separate parts and joined together as part of the manufacturing process of the antenna 400. The dimensions of all the above elements are definitive of the electromagnetic performance of the radiator (e.g. input impedance, currents distribution, etc.) and, hence, their dimensions should be defined during the design of the antenna.

[0061] Of particular importance may be the length and the width of all the three arms 42, 43a, 43b of each IFA element 40, the height and the width of the feeding and shorting parts, and also the position of the feeding part 41. Note that for the implementation of the 'lowfrequency-region' radiator the four multi-arm IFA elements 40 should be at least substantially identical.

[0062] Finally, the dipole structure 46 that is implementing the 'high-frequency-region' radiator may be placed in the middle of employed ground plane 49, in the free area that is formed between the four multi-arm IFA elements 40-1, 40-2, 40-3, 40-4. This dipole structure 46 can be implemented with the use of any of the well-known technologies for such wideband, dual-linearly polarized (slant ±45 degrees) directive, dipole radiators.

[0063] The top-view of the embodiment of Fig. 4 is depicted in **Fig. 5**. As it is shown in Fig. 5, the IFA parts of the 'low-frequency-region' radiator 40 and the 'high-frequency-region' dipole structure 46 may be located in a common physical volume or housing. As a result, the electromagnetic interaction of all these parts may be expected to be strong. The operation of each of these two radiators 40, 46 may strongly be influenced by the presence of the other one, and, hence, they may be simultaneously designed and developed.

[0064] Turning now to **Fig. 6**, an example embodiment of a feeding network 60 for the proposed compact and multiband antenna element 400 is shown.

[0065] The feeding network 60 is needed for the operation and the optimal performance of the proposed antenna concept. As far as the 'high-frequency-region' dipole structure 46 is concerned, the feeding network 60 may be kept simple and may be composed only of 50-Ohms transmission lines between feeding points 60a and 60b of the dipole structure 46 and points 61a and 61b at which the 'high-frequency-region' dipole structure 46 is fed and interconnected with remaining radio circuitry. In some embodiments, impedance matching elements may be added on these transmission lines in order to further improve the 'high-frequency-region' dipole impedance matching.

[0066] For the 'low-frequency-region' IFA structure 40 embodiments of the feeding network 60 may be slightly more sophisticated. The four multi-arm IFA elements 40-1 to 40-4 for the implementation of the 'low-frequency-region' radiator 40 may be fed in pairs in order to achieve the required polarization purity and the operating bandwidth performance. Specifically, each of the pairs of IFA elements located on two diagonally opposite corners of the square configuration may be fed differentially from the same antenna port. That is to say, one antenna port may differentially feed IFA elements 40-1 and 40-2, while another antenna port may differentially feed IFA elements 40-3 and 40-4. Differential feeding means that signals fed to the appropriate IFA elements are out-of-phase. In such a case the signals fed to the oppositely lying IFA elements 40-1 and 40-2 (or 40-3 and 40-4) have to be equal in amplitude and their phase difference should be substantially 180° for each frequency over the desired bandwidth. Such an excitation is called differential feeding of the antenna. It enables good polarization decoupling over the very wide frequency range.

[0067] The feeding network that implements this functionality for the 'low-frequency-region' radiator 40 is also shown in Fig. 6. Assuming that the two main antenna ports of the 'low-frequency-region' radiator are those at points 62 and 65 (these two ports correspond to the two orthogonal polarizations of the 'low-frequency-region' radiator 40), the signal of each of these ports 62, 65 should feed differentially the two IFA elements 40-1 and 40-2 (or 40-3 and 40-4) located at opposite corners. For example, the signal at antenna port 62 may be guided to a balanced power divider 63 that creates two identical and phase-matched instances of the same signal. These two instances of the same signal may be guided to the two feeding points (feeding pins) 64a and 64b of the two IFA elements 40-1, 40-2 that are located on the two opposite corners of ground plane 49. The above mentioned differential feeding of these two IFA elements 40-1, 40-2 may be guaranteed by designing the electrical length of the lines between the power divider 63 and the IFA feeding points 64a and 64b to be 180*n degrees (n = 1, 3, 5..) out-of-phase (equivalently, the physical length of this pair of lines should differ by n*λ/2 (n = 1, 3, 5..)). Unless otherwise dictated by mechanical constraints, the preferred phase offset between these lines should possibly be chosen to be the minimum possible (i.e. 180 degrees). With the use of this feeding network, the RF signal fed at the antenna port 62 will be feeding the IFA elements 40-1, 40-2 that are located on the top left and the bottom right corners of the radiator and will be radiated through this pair of IFA elements 40-1, 40-2 as a purely linearly polarized wave. The polarization of this wave will follow the orientation of these two IFA-elements 40-1, 40-2, and will therefore extend in the plane defined by the diagonal that connects the top left and the bottom right corners 47-1, 47-2 and the direction of maximum radiation (normal to the antenna PCB 49).

[0068] Similarly to the port 62, the RF signal fed at port 65 will be guided to power divider 66 and then in a similarly differential manner will be fed at the two feeding pins 67a and 67b of the two remaining IFA elements 40-3 and 40-4 (located at the top right and bottom left corners 47-3, 47-4 of the antenna PCB). This part of the feeding network and the latter IFA elements 40-3, 40-4 will be eventually implementing the orthogonal polarization of the 'low-frequency-region' radiator.

[0069] Additionally to the aforementioned functionality of the feeding network 60, the feeding network part corresponding to the 'low-frequency-region' radiator 40 may be also used to improve the isolation between the 'low-frequency-region' and the 'high-frequency-region' radiators 40, 46. It is often the case that the 'low-frequency-region' radiator becomes resonant at the operating frequency of the 'high-frequency-region' radiator. As a result, and given the fact that the two radiators 40, 46 are co-polarized, an unwanted effect of power being coupled from the 'high-frequency-region' radiator 46 to the 'low-frequency-region' radiator 40 can be observed. To mitigate the impact of such an effect, 'high-frequency-region' band-stop elements may be included in the feeding network of the 'low-frequency-region' feeding network so as to prevent power radiated from the 'high-frequency-region' dipole 46 to be received at the 'low-frequency-region' antenna ports 62, 65. Hence, a feeding network of the inverted-F antenna structure 40 may comprise band stop elements configured to decouple the dipole antenna structure 46 from the inverted-F antenna structure 40. Such band stop elements may e.g. be quarter-wavelength ('high-frequency-region' wavelength) open stubs 68 and 69 and may be used between the low-frequency-region' antenna ports 62 and 65 and the corresponding power dividers 63 and 66. Hence, a band stop element may comprise an open stub 68, 69 between an antenna port 62, 65 for the IFA structure and a power divider 63, 66 of the feeding network. A length of the open stub 68, 69 may substantially correspond to a quarter wavelength of a center frequency of the second frequency band. The exact design of such band-stopping features can be optimized so as the required isolation performance to be achieved.

[0070] In an example implementation, the feeding network 60 or parts thereof may be implemented in microstrip technology on the back side of the PCB on which the two radiators 40, 46 may be assembled. In other possible implementations, the feeding network 60 can be designed on the top side of the PCB, e.g. on the same side with the 3D parts of the radiators 40, 46, or it can be even implemented without the use of PCB based elements, but with the use of cabled transmission lines (e.g. coaxial lines) and cable-based or packaged power dividers. Nevertheless, in all the above cases, the functionality of the feeding network 60 needs to be identical for the optimal operation of the proposed antenna concept.

[0071] Turning now to **Fig. 7**, an alternative implementation of the IFA elements 40-1 to 40-4 of the 'low-frequency-region' radiator 40 is depicted. According to this example embodiment, the inner edge of the central arm 42 of each IFA element 40-1 to 40-4 can be split in two smaller arms 42a, 42b that extend in parallel with the passive arms 43a, 43b of the same IFA element, forming an orthogonal configuration. In other words, the fed arm 42 may be split at its inner end facing the dipole antenna structure 46 and/or the symmetry center 44 into a first and a second fed arm portion 42a, 42b, similar to a dove tail. Thereby the first fed arm portion 42a may extend in parallel to the first passive arm 43a and the second fed arm portion 42b may extend in parallel to the second passive arm 43b. At the same time the first and a second fed arm portions 42a, 42b may extend coplanar with the passive arms 43a, 43b of the respective IFA element and in parallel to the ground plane 49.

[0072] In some embodiments, the central arm 42 may be split immediately after the feeding point 41 extending vertically from the ground plane to the central arm 42. In this way no modifications of the feeding mechanism are required. The exact dimensions of the smaller arms 42a, 42b may be designed so as to optimize the impedance performance of the respective IFA elements 40-1 to 40-4. For example, the length of the smaller arms 42a, 42b may vary from the minimum possible value (which in the general case is 0) to the maximum possible value, which may be defined by the length of the passive arms 43a, 43b of the same IFA element. An advantage of this implementation of the 'low-frequency-region' radiator 40 is that it may secure additional footprint (free area) in the middle or center of the ground plane 49 for the installation and the optimal design of the 'high-frequency-region' dipole structure 46.

[0073] For example, in **Fig. 8**, the 'high-frequency-region' dipole structure 46 of Fig. 4 has been substituted with an alternative dipole design (square dipole), which in some cases may exhibit improved impedance matching performance. Furthermore, the additional available footprint for the 'high-frequency-region' dipole structure may allow for the installation of the 'high-frequency-region' dipole 46 at 45° offset with regards of the polarization directions of the 'low-frequency-region' radiator 40, as shown in **Fig. 9**, enabling the further improvement of the isolation between the 'high-frequency-region' and 'low-frequency-region' radiators.

[0074] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

[0075] It is further to be noted that methods disclosed in the specification or in the claims may be implemented by a device having means for performing each of the respective steps of these methods.

[0076] Further, it is to be understood that the disclosure of multiple steps or functions disclosed in the specification or claims may not be construed as to be within the specific order. Therefore, the disclosure of multiple steps or functions will not limit these to a particular order unless such steps or functions are not interchangeable for technical reasons. Furthermore, in some embodiments a single step may include or may be broken into multiple sub steps. Such sub steps may be included and part of the disclosure of this single step unless explicitly excluded.

Claims

1. A multiband antenna (400), comprising:

   a ground plane (49);
   a dipole antenna structure (46) coupled to the ground plane (49) and configured to radiate electromagnetic waves in a first frequency band; and
   an inverted-F antenna structure (40) coupled to the ground plane (49) and configured to radiate electromagnetic waves in a second frequency band,
   wherein frequencies of the first frequency band are higher than frequencies of the second frequency band,
   wherein the dipole antenna structure (46) and the inverted-F antenna structure (40) are arranged concentrically on the ground plane (49), and wherein the dipole antenna structure (46) is encompassed by the inverted-F antenna structure (40).

2. The multiband antenna (400) of claim 1, wherein the inverted-F antenna structure (40) comprises a first pair of differentially fed inverted-F antenna elements (40-1; 40-2) and a second pair of differentially fed inverted-F antenna elements (40-3; 40-4).

3. The multiband antenna (400) of claim 1, wherein the inverted-F antenna structure (40) comprises four inverted-F antenna elements (40-1; 40-2; 40-3; 40-4), wherein each inverted-F antenna element is arranged at a different corner (47) of a square area spanned by the four inverted-F antenna elements (40-1; 40-2; 40-3; 40-4).

4. The multiband antenna (400) of claim 1, wherein the inverted-F antenna structure (40) is configured to radiate electromagnetic waves in at least two polarizations and comprises, per polarization, a first and a second inverted-F antenna elements (40-1; 40-2; 40-3; 40-4) arranged point symmetrically with respect to a symmetry center (44) of the inverted-F antenna structure.

5. The multiband antenna (400) of claim 4, wherein the first and the second inverted-F antenna elements (40-1; 40-2; 40-3; 40-4) of a polarization are coupled to an antenna port (62; 65) via a power divider (63; 66), wherein electrical lengths of lines between the power divider (63; 66) and respective feedings points associated to the first and the second inverted-F antenna elements (40-1; 40-2; 40-3; 40-4) differ by n*180°, n denoting an uneven integer.

6. The multiband antenna (400) of claim 4, wherein the first and the second inverted-F antenna elements (40-1; 40-2) of a first polarization are arranged at first diagonally opposing corner regions (47) of the ground plane (49) and wherein the first and the second inverted-F antenna elements (40-3; 40-4) of a second polarization are arranged at second diagonally opposing corner regions (47) of the ground plane (49).

7. The multiband antenna (400) of claim 1, wherein the inverted-F antenna structure (40) comprises a plurality of identically dimensioned inverted-F antenna elements (40-1; 40-2; 40-3; 40-4), wherein an inverted-F antenna element comprises a first and a second passive arm (43a; 43b) coupled at right angles to each other and a fed arm (42) coupled to the first and the second passive arm in a 45° angle, respectively.

8. The multiband antenna (400) of claim 7, wherein the fed arm (42) and the first and the second passive arms (43a; 43b) are arranged co-planar in parallel to the ground plane (49).

9. The multiband antenna (400) of claim 7, wherein the fed arm (42) and the first and the second passive arms join (43a; 43b) in a corner region (45) of the inverted-F antenna element, wherein the corner region (45) of the inverted-F antenna element is coupled to a corner region (47) of the ground plane via a vertically extending grounding post (43).

10. The multiband antenna (400) of claim 7, wherein a main axis of the fed arm (42) points to the dipole antenna structure (46) and/or a symmetry center (44) of the inverted-F antenna structure (40).

11. The multiband antenna (400) of claim 7, wherein a main axis of the first passive arm (43a) extends in parallel to a first side of the ground plane (49), and wherein a main axis of the second passive arm (43b) extends in parallel to a second side of the ground plane (49), the second side being rectangular to the first side.

12. The multiband antenna (400) of claim 7, wherein the fed arm (42) is split at its inner end facing the dipole antenna structure (46) and/or a symmetry center (44) of the inverted-F antenna structure into a first and a second fed arm portion (42a; 42b), wherein the first fed arm (42a) portion extends in parallel to the first passive arm (43a) and wherein the second fed arm portion (42b) extends in parallel to the second passive arm (43b).

13. The multiband antenna of claim 1, wherein a feeding network of the inverted-F antenna structure comprises band stop elements configured to decouple the dipole antenna structure from the inverted-F antenna structure.

Patentansprüche

1. Mehrbandantenne (400), umfassend:

   eine Grundplatte (49);

   eine dipole Antennenstruktur (46), an die Grundplatte (49) gekoppelt und konfiguriert für das Ausstrahlen elektromagnetischer Wellen in einem ersten Frequenzband;

   eine Inverted-F-Antennenstruktur (40), an die Grundplatte (49) gekoppelt und konfiguriert für das Ausstrahlen elektromagnetischer Wellen in einem zweiten Frequenzband;

   wobei die Frequenzen des ersten Frequenzbands höher sind als die Frequenzen des zweiten Frequenzbands,

   wobei die dipole Antennenstruktur (46) und die Inverted-F-Antennenstruktur (40) konzentrisch auf der Grundplatte (49) ausgerichtet sind und wobei die dipole Antennenstruktur (46) von der Inverted-F-Antennenstruktur (40) umfasst wird.

2. Die Mehrbandantenne (400) nach Anspruch 1, wobei die Inverted-F-Antennenstruktur (40) ein erstes Paar differentiell gespeister Inverted-F-Antennenelemente (40-1; 40-2) und ein zweites Paar differentiell gespeister Inverted-F-Antennenelemente (40-3; 40-4) umfasst.

3. Die Mehrbandantenne (400) nach Anspruch 1, wobei die Inverted-F-Antennenstruktur (40) vier Inverted-F-Antennenelemente (40-1; 40-2; 40-3; 40-4) umfasst, wobei jedes Inverted-F-Antennenelement in einer anderen Ecke (47) eines quadratischen Bereichs angeordnet ist, der von den vier Inverted-F-Antennenelementen (40-1; 40-2; 40-3; 40-4) gebildet wird.

4. Die Mehrbandantenne (400) nach Anspruch 1, wobei die Inverted-F-Antennenstruktur (40) konfiguriert ist für das Ausstrahlen elektromagnetischer Wellen in zumindest zwei Polarisierungen und pro Polarisierung ein erstes und ein zweites Inverted-F-Antennenelement (40-1; 40-2; 40-3; 40-4) umfasst, punktsymmetrisch zu einem Symmetriezentrum (44) der Inverted-F-Antennenstruktur angeordnet.

5. Die Mehrbandantenne (400) nach Anspruch 4, wobei die ersten und die zweiten Inverted-F-Antennenelemente (40-1; 40-2; 40-3; 40-4) einer Polarisierung über einen Leistungsteiler (63; 66) an einen Antennenport (62; 65) gekoppelt sind, wobei elektrische Längen von Leitungen zwischen dem Leistungsteiler (63; 66) und entsprechenden, mit den ersten und den zweiten Inverted-F-Antennenelementen (40-1; 40-2; 40-3; 40-4) assoziierten Einspeisungspunkten um *n**180°, *n* voneinander abweichen, eine ungerade ganze Zahl anzeigend.

6. Die Mehrbandantenne (400) nach Anspruch 4, wobei die ersten und zweiten Inverted-F-Antennenelemente (40-1; 40-2) einer ersten Polarisierung an ersten einander diagonal gegenüberliegenden Eckbe-

reichen (47) der Grundplatte (49) angeordnet sind, und wobei die ersten und zweiten Inverted-F-Antennenelemente (40-3; 40-4) einer zweiten Polarisierung an zweiten einander diagonal gegenüberliegenden Eckbereichen (47) der Grundplatte (49) angeordnet sind.

7. Die Mehrbandantenne (400) nach Anspruch 1, wobei die Inverted-F-Antennenstruktur (40) eine Vielzahl identisch dimensionierter Inverted-F-Antennenelemente (40-1; 40-2; 40-3; 40-4) umfasst, wobei ein Inverted-F-Antennenelement einen ersten und einen zweiten passiven Arm (43a; 43b) umfasst, die in rechten Winkeln aneinander und darüber hinaus an einen Fed-Arm (42) gekoppelt sind, der seinerseits in einem Winkel von 45° an den ersten und an den zweiten passiven Arm gekoppelt ist.

8. Die Mehrbandantenne (400) nach Anspruch 7, wobei der Fed-Arm (42) sowie der erste und der zweite passive Arm (43a; 43b) koplanar parallel zur Grundplatte (49) angeordnet sind.

9. Die Mehrbandantenne (400) nach Anspruch 7, wobei der Fed-Arm (42) sowie der erste und der zweite passive Arm (43a; 43b) in einem Eckbereich (45) des Inverted-F-Antennenelements zusammenkommen, wobei der Eckbereiche (45) des Inverted-F-Antennenelements über einen vertikal angeordneten Erdungspfosten (43) an einen Eckbereiche (47) der Grundplatte gekoppelt ist.

10. Die Mehrbandantenne (400) nach Anspruch 7, wobei eine Hauptachse des Fed-Arms (42) auf eine dipole Antennenstruktur (46) und/oder ein symmetrisches Zentrum (44) der Inverted-F-Antennenstruktur (40) ausgerichtet ist.

11. Die Mehrbandantenne (400) nach Anspruch 7, wobei eine Hauptachse des ersten passiven Arms (43a) parallel zu einer ersten Seite der Grundplatte (49) angeordnet ist und wobei eine Hauptachse des zweiten passiven Arms (43b) parallel zu einer zweiten Seite der Grundplatte (49) angeordnet ist, wobei die zweite Seite einen rechten Winkel mit der ersten Seite bildet.

12. Die Mehrbandantenne (400) nach Anspruch 7, wobei der Fed-Arm (42) an seinem inneren Ende gegenüber der dipolen Antennenstruktur (46) und/oder dem symmetrischen Zentrum (44) der ersten Inverted-F-Antennenstruktur in einen ersten und einen zweiten Fed-Arm-Abschnitt (42a; 42b) aufgespalten ist, wobei der erste Fed-Arm-Abschnitt (42a) parallel zum ersten passiven Arm (43a) und wobei die zweite Fed-Arm-Abschnitt (42b) parallel zu dem zweiten passiven Arm (43b) angeordnet ist.

13. Die Mehrbandantenne nach Anspruch 1, wobei ein versorgendes Netzwerk der Inverted-F-Antennenstruktur Bandsperr-Elemente umfasst, die konfiguriert sind für das entkoppeln der dipolen Antennenstruktur von der Inverted-F-Antennenstruktur.

Revendications

1. Antenne multibande (400), comprenant :

   un plan de sol (49) ;
   une structure d'antenne dipôle (46) couplée au plan de sol (49) et configurée pour envoyer des ondes électromagnétiques dans une première bande de fréquences ; et
   une structure d'antenne en F inversé (40) couplée au plan de sol (49) et configurée pour envoyer des ondes électromagnétiques dans une deuxième bande de fréquences,
   dans laquelle les fréquences de la première bande de fréquences sont supérieures aux fréquences de la deuxième bande de fréquences,
   dans laquelle la structure d'antenne dipôle (46) et la structure d'antenne en F inversé (40) sont disposées de manière concentrique sur le plan de sol (49), et dans laquelle la structure d'antenne dipôle (46) est englobée par la structure d'antenne en F inversé (40).

2. Antenne multibande (400) selon la revendication 1, dans laquelle la structure d'antenne en F inversé (40) comprend une première paire d'éléments d'antenne en F inversé à alimentation différentielle (40-1 ; 40-2) et une deuxième paire d'éléments d'antenne en F inversé à alimentation différentielle (40-3 ; 40-4).

3. Antenne multibande (400) selon la revendication 1, dans laquelle la structure d'antenne en F inversé (40) comprend quatre éléments d'antenne en F inversé (40-1 ; 40-2 ; 40-3 ; 40-4), dans laquelle chaque élément d'antenne en F inversé est disposé à un coin différent (47) d'une zone carrée formée par les quatre éléments d'antenne en F inversé (40-1 ; 40-2 ; 40-3 ; 40-4).

4. Antenne multibande (400) selon la revendication 1, dans laquelle la structure d'antenne en F inversé (40) est configurée pour envoyer des ondes électromagnétiques dans au moins deux polarisations et comprend, par polarisation, un premier et un deuxième éléments d'antenne en F inversé (40-1 ; 40-2 ; 40-3 ; 40-4) disposés à symétrie ponctuelle par rapport à un centre de symétrie (44) de la structure d'antenne en F inversé.

5. Antenne multibande (400) selon la revendication 4, dans laquelle le premier et le deuxième éléments

d'antenne en F inversé (40-1 ; 40-2 ; 40-3 ; 40-4) d'une polarisation sont couplés à un port d'antenne (62 ; 65) par l'intermédiaire d'un diviseur de puissance (63 ; 66), dans laquelle des longueurs électriques de lignes entre le diviseur de puissance (63 ; 66) et des points d'alimentation respectifs associés au premier et au deuxième éléments d'antenne en F inversé (40-1 ; 40-2 ; 40-3 ; 40-4) diffèrent de *n** 180°, *n* indiquant un nombre entier impair.

6. Antenne multibande (400) selon la revendication 4, dans laquelle le premier et le deuxième éléments d'antenne en F inversé (40-1 ; 40-2) d'une première polarisation sont disposés dans des premières régions de coin opposées en diagonale (47) du plan de sol (49) et dans laquelle le premier et le deuxième éléments d'antenne en F inversé (40-3 ; 40-4) d'une deuxième polarisation sont disposés dans des deuxièmes régions de coin opposées en diagonale (47) du plan de sol (49).

7. Antenne multibande (400) selon la revendication 1, dans laquelle la structure d'antenne en F inversé (40) comprend une pluralité d'éléments d'antenne en F inversé dimensionnés de manière identique (40-1 ; 40-2 ; 40-3 ; 40-4), dans laquelle un élément d'antenne en F inversé comprend un premier et un deuxième bras passifs (43a ; 43b) couplés à angle droit l'un par rapport à l'autre et un bras d'alimentation (42) couplé au premier et au deuxième bras passifs selon un angle de 45°, respectivement.

8. Antenne multibande (400) selon la revendication 7, dans laquelle le bras d'alimentation (42) et le premier et le deuxième bras passifs (43a ; 43b) sont disposés de façon coplanaire parallèlement au plan de sol (49).

9. Antenne multibande (400) selon la revendication 7, dans laquelle le bras d'alimentation (42) et le premier et le deuxième bras passifs se rejoignent (43a ; 43b) dans une région de coin (45) de l'élément d'antenne en F inversé, dans laquelle la région de coin (45) de l'élément d'antenne en F inversé est couplée à une région de coin (47) du plan de sol par l'intermédiaire d'une borne de mise à la terre qui s'étend verticalement (43).

10. Antenne multibande (400) selon la revendication 7, dans laquelle un axe principal du bras d'alimentation (42) est orienté vers la structure d'antenne dipôle (46) et/ou un centre de symétrie (44) de la structure d'antenne en F inversé (40).

11. Antenne multibande (400) selon la revendication 7, dans laquelle un axe principal du premier bras passif (43a) s'étend parallèlement à un premier côté du plan de sol (49), et dans laquelle un axe principal du deuxième bras passif (43b) s'étend parallèlement à un deuxième côté du plan de sol (49), le deuxième côté étant à angle droit par rapport au premier côté.

12. Antenne multibande (400) selon la revendication 7, dans laquelle le bras d'alimentation (42) est séparé, au niveau de son extrémité intérieure en face de la structure d'antenne dipôle (46) et/ou d'un centre de symétrie (44) de la structure d'antenne en F inversé, en une première et une deuxième parties de bras d'alimentation (42a ; 42b), dans laquelle la première partie de bras d'alimentation (42a) s'étend parallèlement au premier bras passif (43a) et dans laquelle la deuxième partie de bras d'alimentation (42b) s'étend parallèlement au deuxième bras passif (43b).

13. Antenne multibande selon la revendication 1, dans laquelle un réseau d'alimentation de la structure d'antenne en F inversé comprend des éléments coupe-bande configurés pour découpler la structure d'antenne dipôle de la structure d'antenne en F inversé.

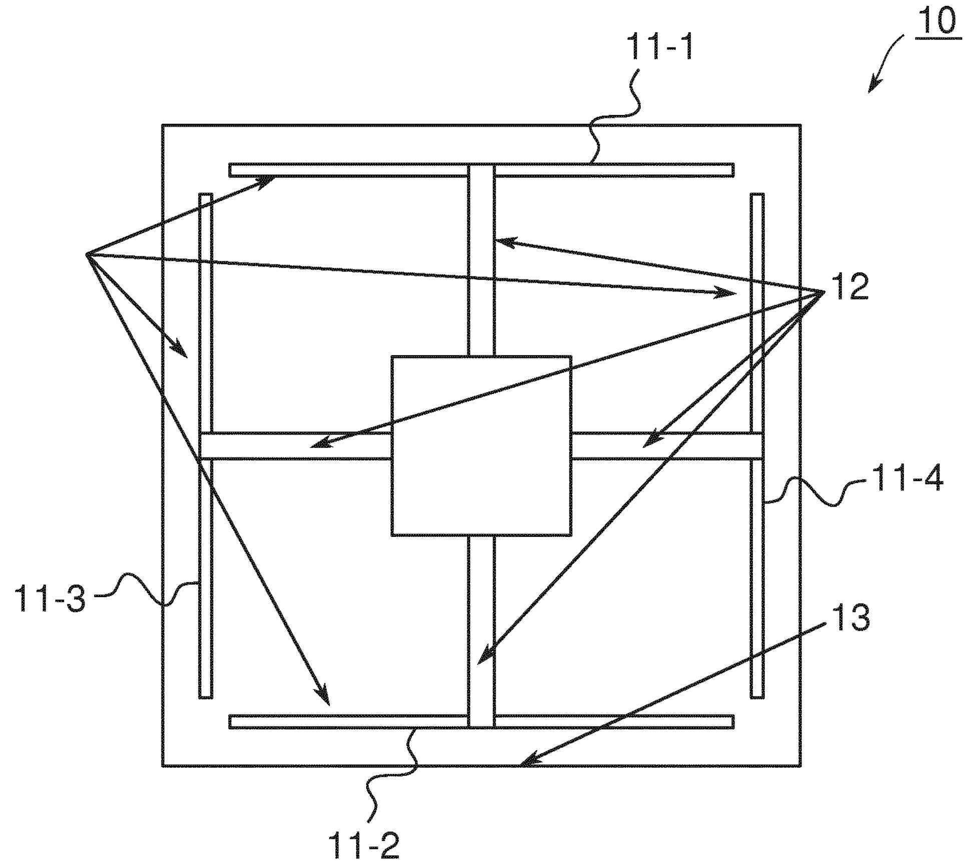
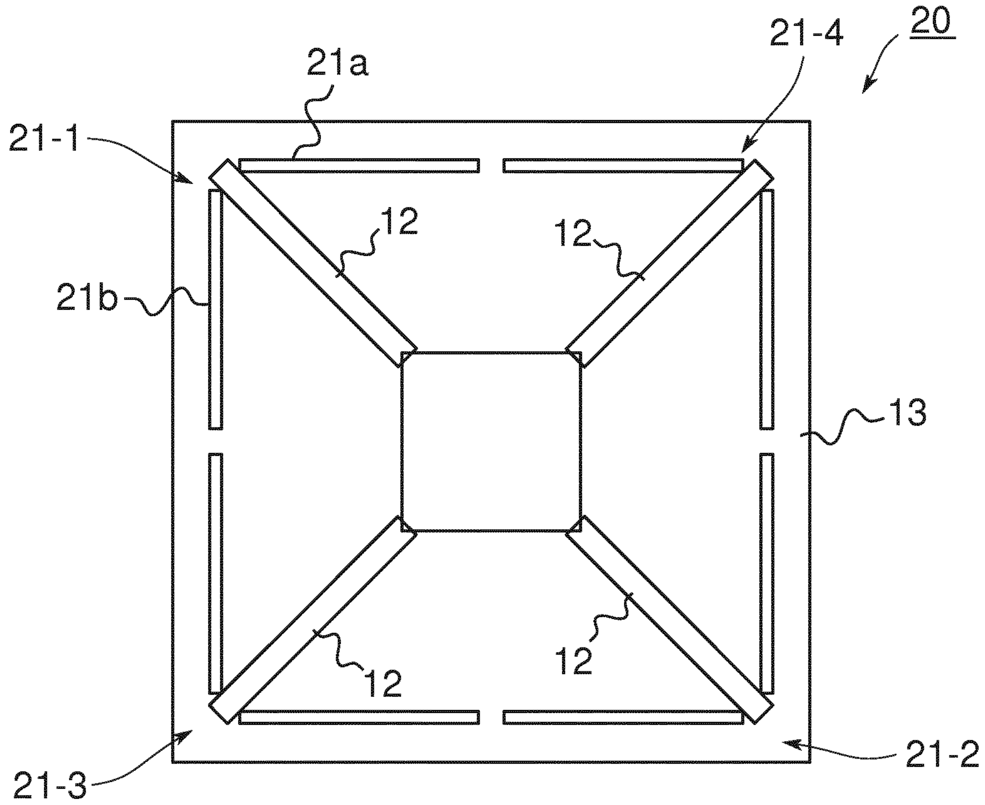
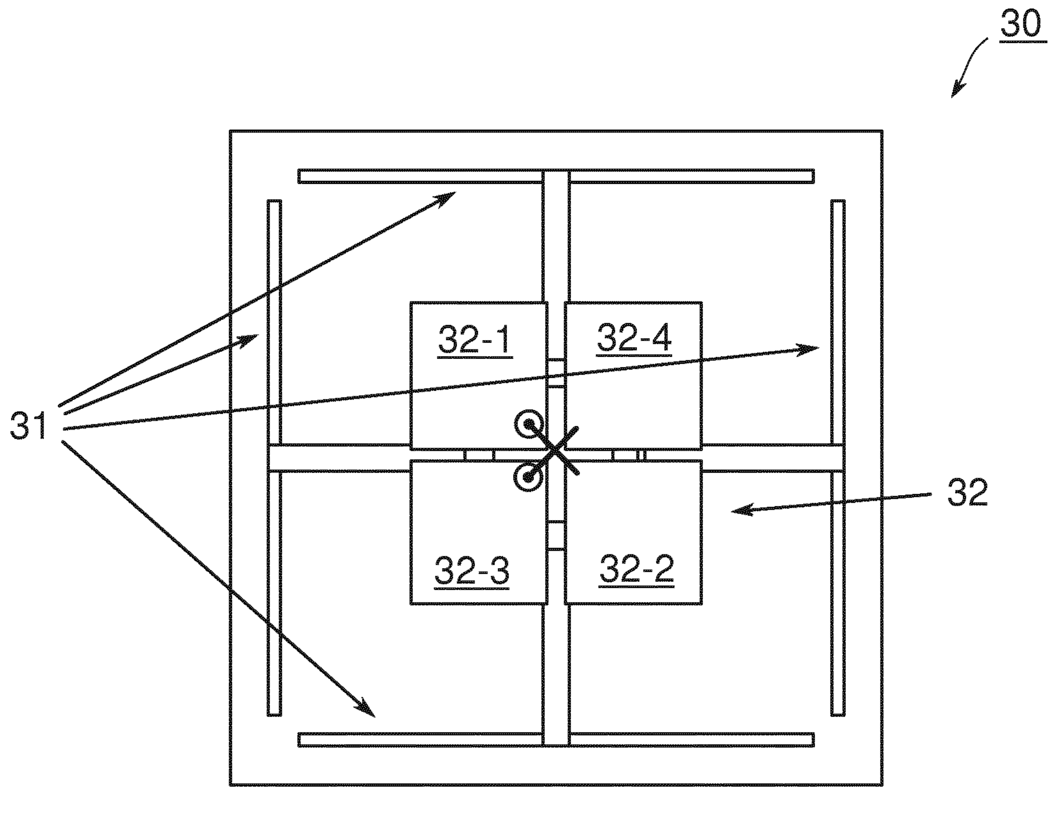


Fig. 1




30
31
32-1
32-4
32-3
32-2
32

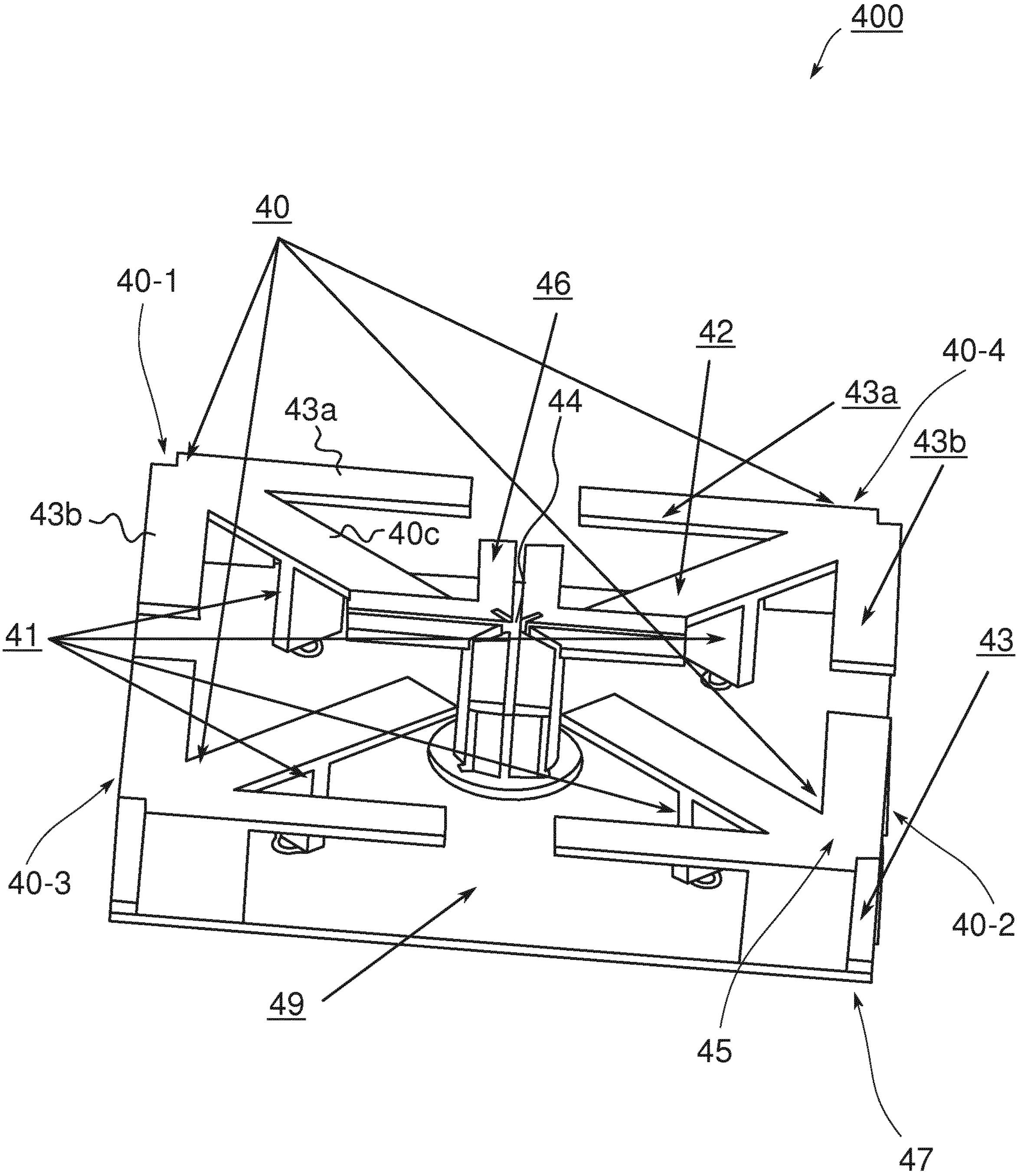


Fig. 4

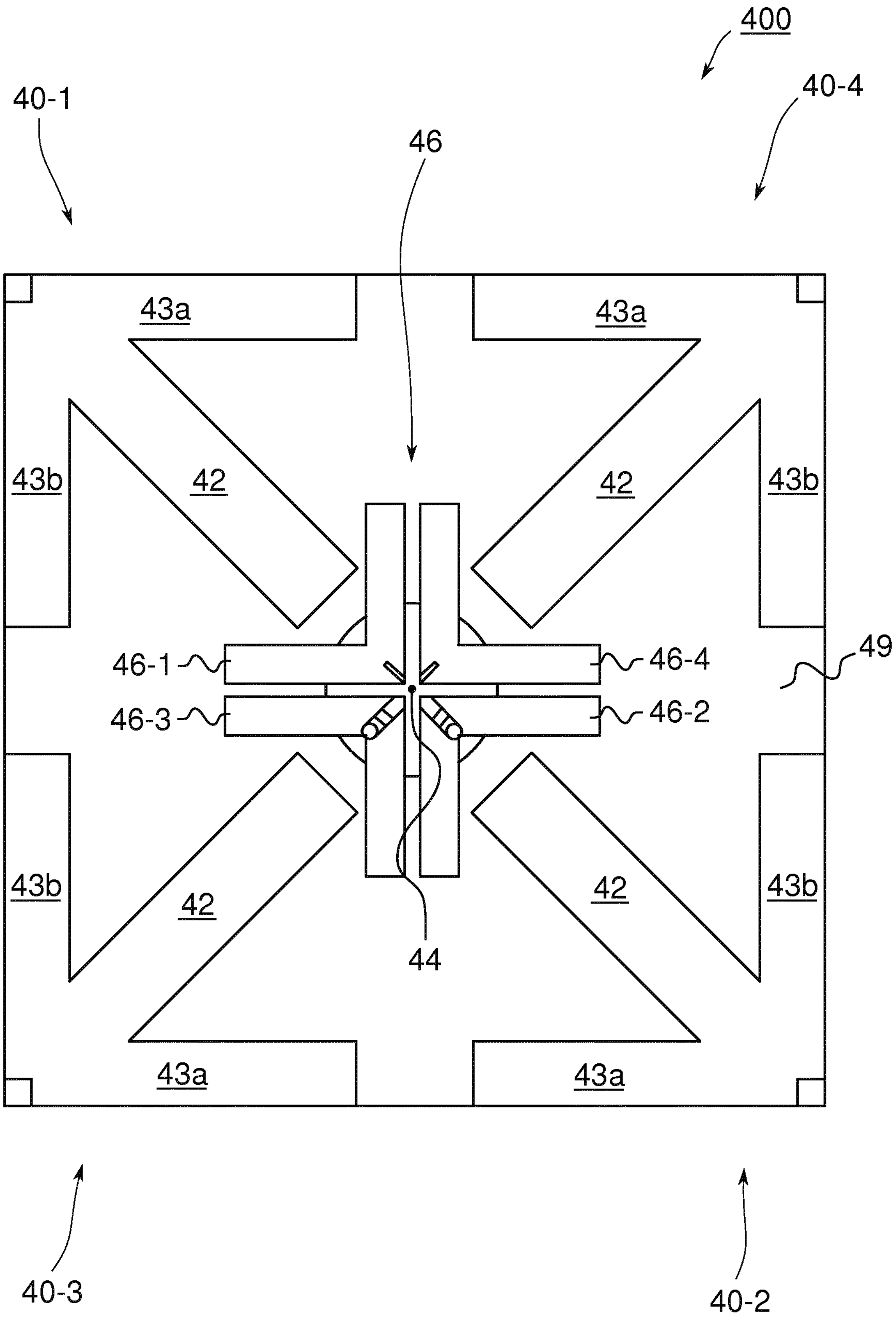

400
40-1
40-4
46
43a
43a
43b
42
42
43b
46-1
46-4
49
46-3
46-2
43b
42
42
43b
44
43a
43a
40-3
40-2

Fig. 5

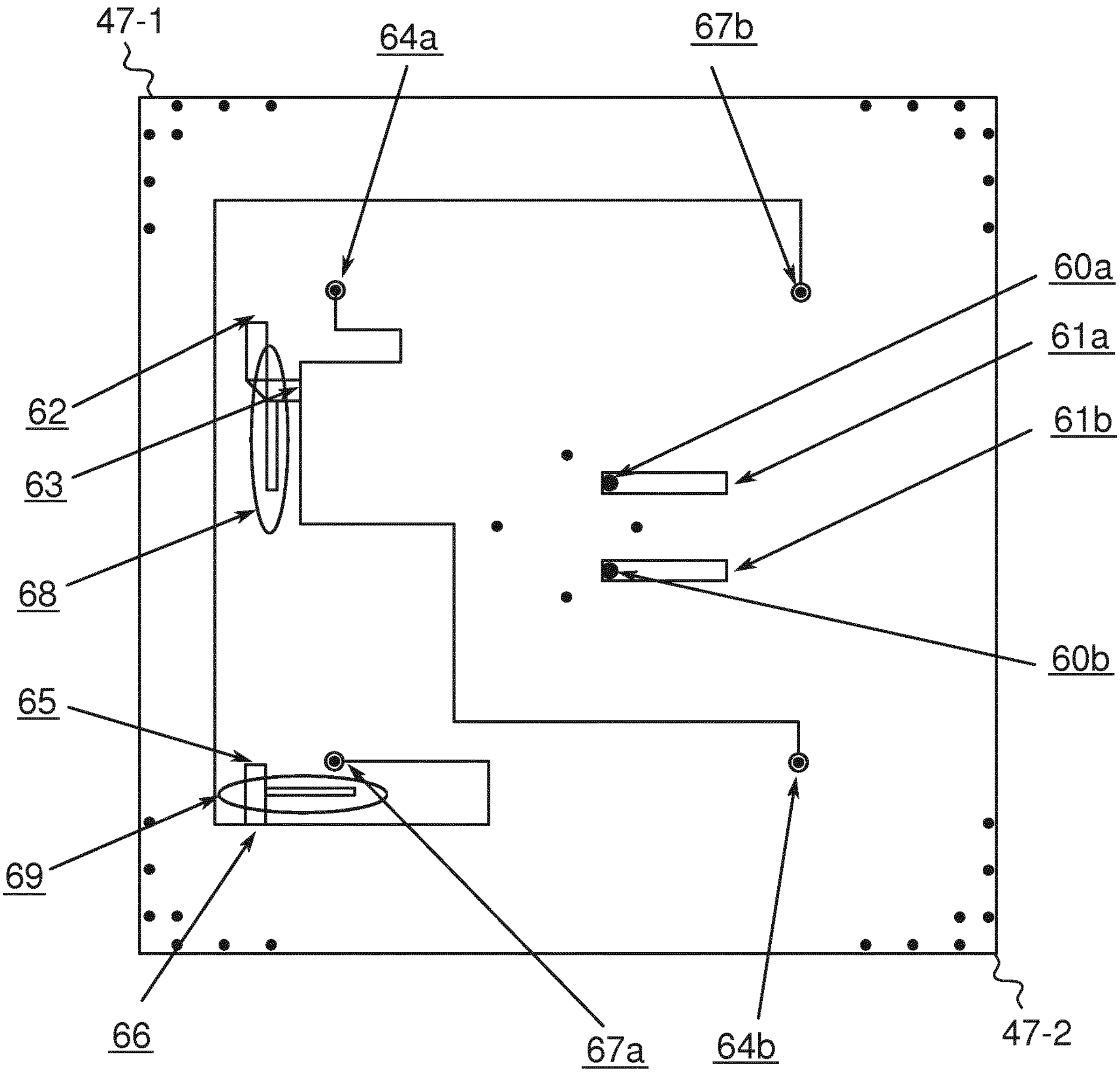


Fig. 6

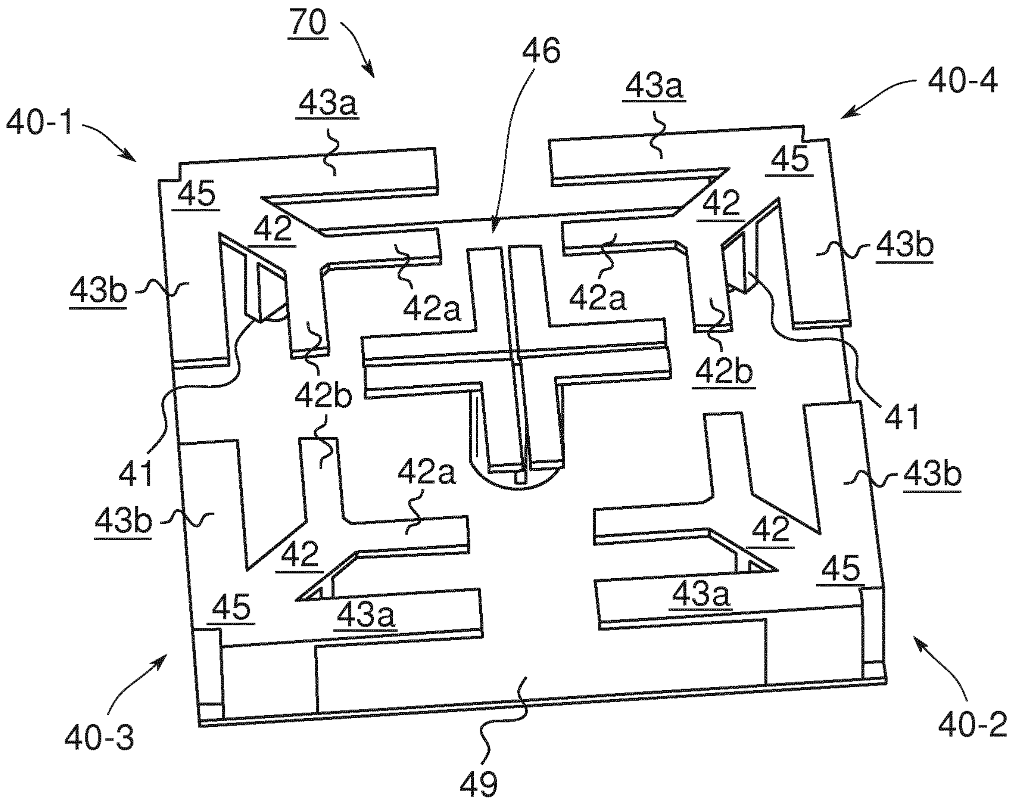

70
46
43a
43a
40-4
40-1
45
45
42
42
43b
42a
42a
43b
42b
42b
41
41
43b
42a
43b
42
42
45
45
43a
43a
40-3
49
40-2

Fig. 7

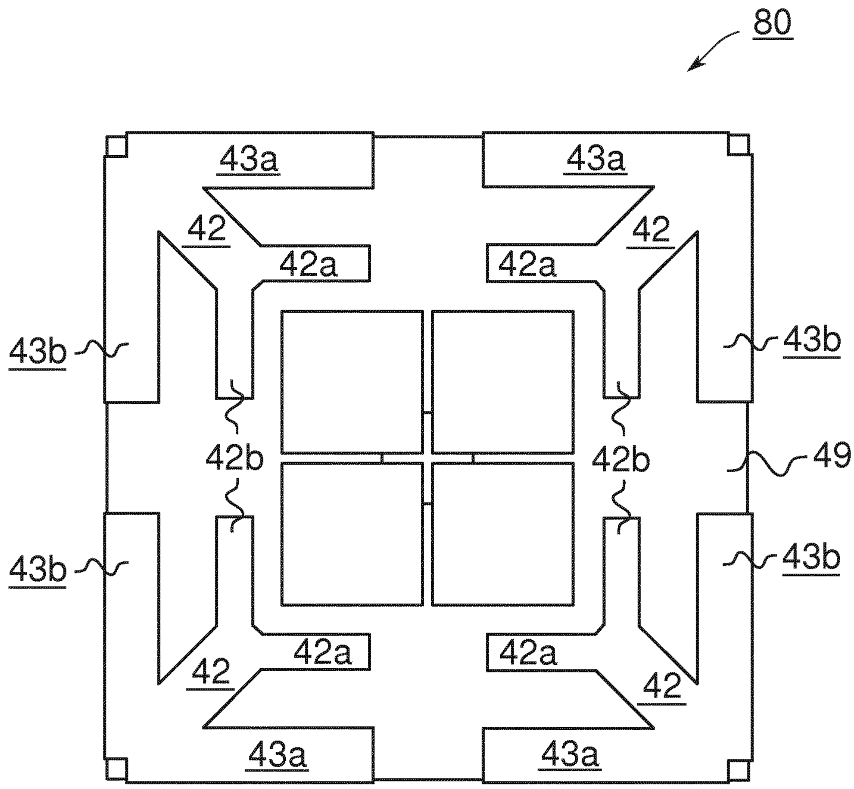

80
43a
43a
42
42
42a
42a
43b
43b
42b
42b
49
43b
43b
42a
42a
42
42
43a
43a

Fig. 8

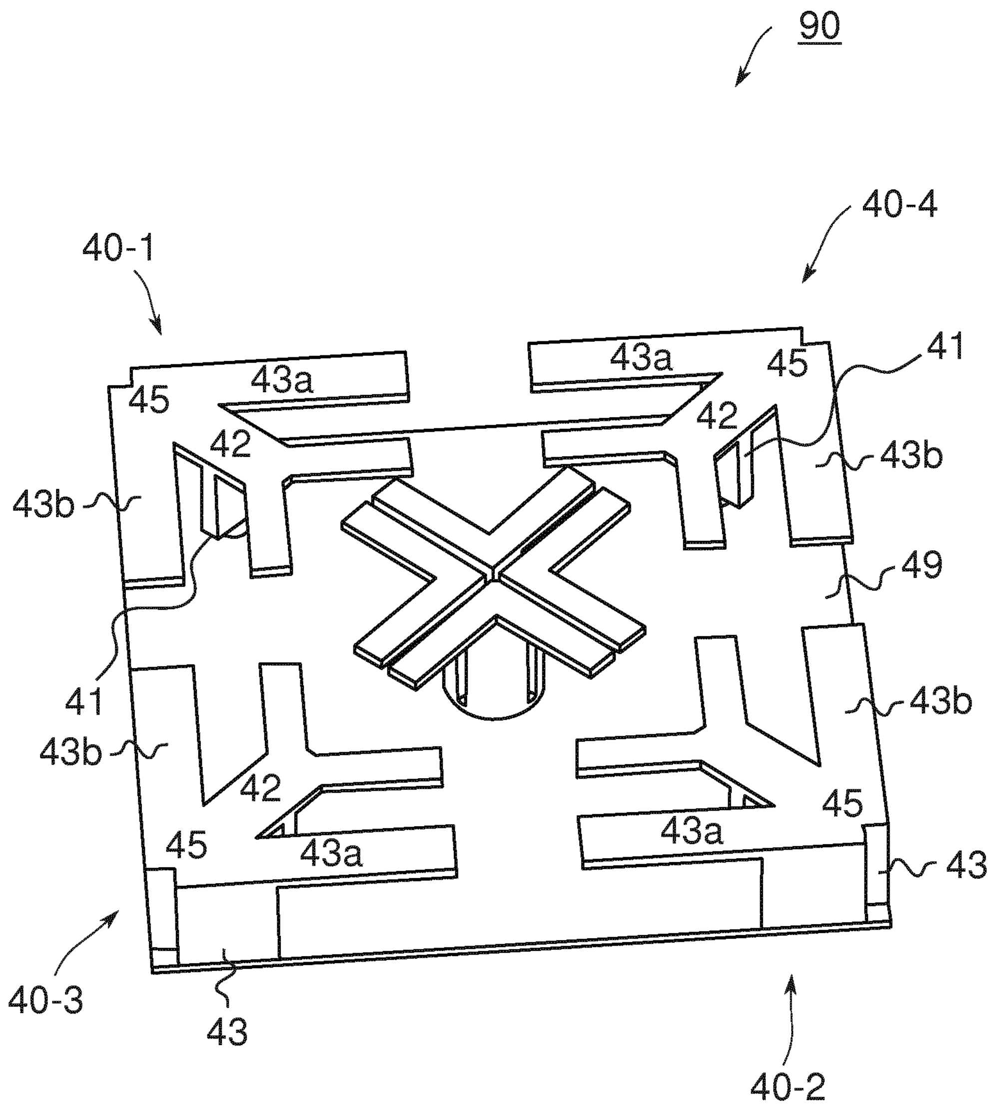

90
40-4
40-1
43a
43a
45
41
45
42
42
43b
43b
41
49
43b
43b
42
45
45
43a
43a
43
40-3
43
40-2

Fig. 9

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.

Patent documents cited in the description

- EP 1487051 A1 **[0008]**
- US 20090278759 A1 **[0008]**
- WO 2008009667 A1 **[0008]**
- US 20120319919 A1 **[0008]**
- US 20120038533 A1 **[0008]**
- WO 0207254 A1 **[0008]**
- US 2012274532 A1 **[0008]**