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(54) **Title**: CIRCULARLY POLARIZED ANTENNA AND FEEDING NETWORK

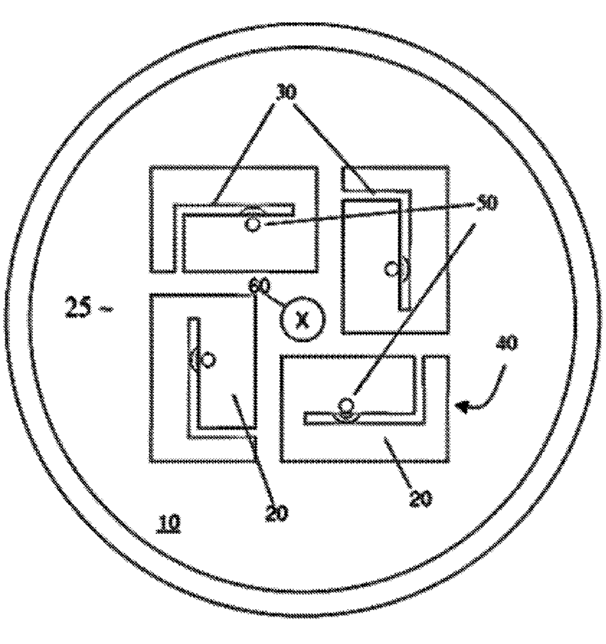

Fig. 1

(57) Abstract: The present invention relates to an antenna for transmitting and/or receiving- electromagnetic waves, in particular microwaves. The antenna comprises a flat ground plane (10) and an array (25) of radiating and/or receiving elements. The radiating and/or receiving element comprises a planar conductor (20). The planar conductor (20) is arranged in parallel to the ground plane (10). An L-shaped slot (30) is arranged in said planar conductor (20).

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Circularly polarized antenna and feeding network

The present invention relates to a transmit and/or receive antenna, handling in particular circularly polarized electromagnetic waves and having a hemispherical radiation pattern. The present invention also relates to a feeding network.

Technical Background

Different approaches for such an antenna with circularly polarized electromagnetic waves having a hemispherical radiation pattern exist. In particular, the global positioning system (GPS) is a global navigation satellite system, which necessitates the use of optimized antennas. GPS satellites broadcast radio signals to enable GPS receivers to determine location and synchronized time. GPS signals include ranging signals, used to measure the distance to the satellite, and navigation messages. The navigation messages include data, used to calculate the position of the satellite in orbit, and information about the time and status of the entire satellite constellation, called the almanac. This information is modulated onto an electromagnetic signal having a predetermined polarization. These antennas have particular requirements that must be met.

For example, a relatively high transmission bandwidth is desirable, such that the antenna can be operated across a large frequency range. Next, the radiation pattern of the antenna should preferably be hemispherical such that signals are received from as many satellites as possible. Finally, a good circular polarization is required across the bandwidth of the antenna. However, other applications for such an antenna are also possible.

Summary of the Invention

Therefore, it is object of the present invention to provide an alternative antenna for receiving and/or transmitting circularly polarized waves. An advantage of embodiments of the present invention is that the antenna can transmit and/or receive across a large frequency range and with a hemispheric radiation pattern and good axial ratio.

This object is solved by the antenna as defined in claim 1. Also the present invention provides a feeding network according to claim 20.

Preferred embodiments are described in the dependent claims.

The antenna for radiating and/or receiving electromagnetic waves according to the present invention comprises a flat ground plane and at least two radiating and/or receiving elements. In a preferred embodiment, four radiating and/or receiving elements are used, each comprising a planar conductor. The planar conductors are arranged in parallel to the ground plane. An L-shaped slot is arranged in each of the said four planar conductors. Each of the 4 planar conductors with L-shaped slots has at least 2 resonances which can be tuned such that they are closely spaced to yield one frequency band. Thereby, the frequency range of the antenna may be increased. The combined 4 planar conductors with the L-shaped slot make up the four radiating and/or receiving elements which, in conjunction with a suitable feeding network, transmit and/or receive circularly polarized waves within said frequency band.

According to a preferred embodiment of the present invention, a radiating and/or receiving element comprises a connector such as a connecting plate or a connecting post or a linear array of connecting posts for connecting each of the 4 planar conductors to the ground plane. The connectors such as connecting plates or the connecting post or linear array of connecting posts are arranged perpendicular to both the ground plane and the planar conductors. The connectors such as the connecting plates or the post or linear array of connecting posts may both support the planar conductors above the ground plane and provide a short between the ground plane and the planar conductors.

Preferably, each radiating and/or receiving element comprises a feed probe. One probe is connected to each of the planar conductors. The probes provide a simple means for connecting to the antenna with appropriate signals in order to transmit and/or receive corresponding electromagnetic waves.

Preferably, in the antenna according to the present invention, the radiating and/or receiving elements are provided by an array of four planar conductors. These planar conductors have essentially the same electromagnetic properties. The four planar conductors are arranged around an axis of symmetry perpendicular to the ground plane. Each one of said planar conductors may be mapped onto an adjacent one of said planar conductors by rotating said one planar conductor by 90° around the axis of symmetry. The particular arrangement of 4 planar conductors creates a hemispherical radiation pattern when fed with a feeding network. The radiation is circularly polarized. This necessitates that the particular radiating and/or receiving elements are fed by the feeding network with signals with a sequential 90° phase difference and of equal amplitude.

According to a particular embodiment of the present invention, said ground plane forms a surface of a ground body having an annular cavity. An axis of symmetry of said annular cavity is perpendicular to the ground plane. Preferably, the annular cavity is arranged essentially parallel to the ground plane such that the annular cavity and the radiating and/or receiving elements are positioned on opposite sides of the ground plane. The axis of symmetry of the radiating and/or receiving elements is essentially identical with the axis of symmetry of the annular cavity.

The annular cavity is basically a wave-guide structure, which may be used around its cut-off frequency. Two spaced plates preferably make up the waveguide and these can be of different radius. The bandwidth of said wave-guide structure is narrow. The annular cavity suppresses the transmission of radiation by the antenna towards the back and enhances the transmission of radiation by the antenna towards the front of the antenna, when it is operated near its resonance frequency. The suppression degrades when moving away from the resonance frequency. Increasing frequency means that the wave-guide is electrically too large. However, this has a very useful side effect, namely improved circular polarization at low elevations. The annular cavity is preferably implemented in such a way that it improves the circular polarization of the antenna over larger frequency ranges by positioning the resonance frequency of the annular cavity below the frequency of operation of the antenna without degrading the overall bandwidth of the antenna. The arrangement of a ground body including one or more ground planes and the annular cavity is advantageous in this respect.

The present invention also provides a feeding network providing electrical coupling with an antenna, namely for connecting radiating and/or receiving elements of the antenna to each other. The feeding network preferably comprises:

one input and a first, second, third and fourth output, each of said outputs being connected to one of said radiating and/or receiving elements via a feed probe (50) of each radiating and/or receiving element, said feeding network (120) being adapted to generate a first, second, third and fourth output signals from a single input signal at the first, second, third and fourth output, respectively, wherein the first output signal is phase shifted by 90° in relation to the second output signal, by 180° in relation to the third output signal and by 270° in relation to the fourth output signal.

The feeding network can also be used in receive mode in which case the input and output signals are reversed. Hence, the present invention also provides a feeding network providing electrical coupling with an antenna, namely for connecting receiving elements of the antenna to each other. The feeding network preferably comprises:

one output and a first, second, third and fourth input, each of said inputs being connected to one of said receiving elements via a feed probe (50) of each radiating and/or receiving element, said feeding network (120) being adapted to receive a first, second, third and fourth input signal, respectively, wherein the first input signal is phase shifted by 90° in relation to the second input signal, by 180° in relation to the third input signal and by 270° in relation to the fourth input signal.

By this arrangement a combination of received or transmitted signals at the individual radiating and/or receiving elements is made. Discrimination between polarizations can be done by introducing a sequential phase shift. The radiating and/or receiving elements can be electromagnetically coupled to some extent because they are closely spaced. In a preferred embodiment, any two neighbouring radiating and/or receiving elements are fed in phase quadrature, i.e. orthogonal, thus isolated from a feeding network perspective. From an antenna perspective, the radiating and/or receiving elements and the feeding network operate as a single radiating and/or receiving structure.

Hereafter, preferred embodiments of the present invention will be described with reference to the accompanying drawings. Please note that the preferred embodiments are merely exemplary. The skilled person may devise alternative implementations of the present invention as defined in the accompanied claims.

Brief Description of the Drawings

Figure 1 shows a top view of an antenna according to a preferred embodiment of the present invention.
Figure 2 shows a side view of the antenna according to the preferred embodiment.
Figure 3 shows a block diagram of a first embodiment of a feeding network for connecting radiating and/or receiving elements of the antenna.
Figure 4 shows a block diagram of a second embodiment of a feeding network for connecting radiating and/or receiving elements of the antenna.
Figure 5 shows a block diagram of a first embodiment of a 180° differential phase splitter for use in the feeding network according to the first or second embodiment.
Figure 6 shows a block diagram of a second embodiment of a 180° differential phase splitter for use in the feeding network according to the first or second embodiment.

Detailed Description of the present invention

The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. Any reference signs in the claims shall not be construed as limiting the scope. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes. Where the term « comprising » is used in the present description and/or claims, it does not exclude the presence of other elements or steps.

Where an indefinite article is used when referring to a singular noun e.g. « a », « an » or « the », this includes a plural of that noun unless something else is specifically stated.

Furthermore, the terms first, second, third and the like in the description and/or in the claims are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

A preferred embodiment of the present invention is depicted in Figure 1, which shows a top view of an antenna. The antenna can be used for transmitting and/or receiving electromagnetic waves, preferably microwaves or radio waves. The antenna comprises a ground plane 10. The ground plane can be essentially circular and preferably made out of an electrically conductive material. Plural radiating and/or receiving elements in an array 25 are arranged on top of said ground plane. The shape as well as the arrangement of radiating and/or receiving elements is instrumental in generating the desired electromagnetic wave. It is desired to have an antenna, which may radiate a circular polarized hemispherical radiation pattern. Additionally, the desired radiation pattern should be maintained across a relatively large frequency bandwidth of the radiated signal. A good circular polarization over this frequency bandwidth should be maintained, while changes in the radiation pattern shape are minimized.

Turning to the particular shape of the radiating and/or receiving elements, it is pointed out that each radiating and/or receiving element comprises a planar conductor 20, which is essentially two-dimensional, i.e. the width and length of the planar conductor is larger by a multiple magnitude of the thickness of the planar conductor 20. The planar conductors can therefore be described as made from sheet material. Each planar conductor has radiating edges of different length, e.g. is preferably rectangular in shape. The surface of the planar conductor 20 is arranged in parallel to the ground plane 10. Each planar conductor comprises an L-shaped slot 30, which may be formed by cutting out said shape from the planar conductor 20. Alternatively, the slot 30 may be etched out or made by any other means.

As indicated above, an outer circumference of the planar conductors preferably has a rectangular shape. The rectangular shape has a short side and a long side. A short leg of the L-shaped slot 30 is arranged in parallel and proximity of a short side of the rectangular shape forming the circumference of the planar conductor 20. The L-shaped slot is preferably completely surrounded at the short edge of the planar conductor by conductive parts of the radiating and/or receiving element, i.e. the L-shaped slot does not extend all the way to the short edge of the radiating and/or receiving element. Furthermore, the short leg extends all the way to the edge forming the long side of the rectangular shape. The long leg of the L-shaped slot is optionally placed between the long sides of the rectangular outer circumference. The L-slot element has at least 2 resonance frequencies. These frequencies may be tuned such that they are closely spaced. Thereby, the overall frequency response of said radiating and/or receiving element represents a relatively broad frequency band. Thus the radiating and/or receiving element is a wideband structure with a low quality factor Q. The quality factor Q is a dimensionless parameter defined by the $f_r/\Delta f$, where f_r is the resonant frequency, Δf is the frequency bandwidth.

Preferably the planar conductor is made out of copper.

Each planar radiating and/or receiving element may be described as a Planar Inverted F antenna. A planar Inverted F Antenna (PIFA) typically consists of a rectangular planar element located above a ground plane, a short circuiting plate or pin, and a feeding mechanism for the planar element.

The at least one ground plane of the antenna in accordance with the present invention plays a significant role in the operation. Excitation of currents in the PIFA cause excitation of currents in the ground plane or ground body. The resulting electromagnetic field is formed by the interaction of the PIFA and an image of itself below the ground plane.

Since each planar conductor 20 is suspended above the ground plane 10, a supporting structure is needed. Therefore, a connector such as a connecting plate 40 or a conductive post or a linear array of conductive posts is arranged between each planar conductor 20 and the ground plane 10. The connecting plate 40 is formed by a rectangular plate, which extends from a short side of the rectangular planar conductor 20 to the ground plane 10. The connecting plate is oriented essentially perpendicular to both ground plane and the planar conductor 20. Each radiating and/or receiving element must be supplied with an electrical signal in order to emit the desired electromagnetic wave or supplies a signal in receive mode. Therefore, a feed probe 50 forms a connection to the respective planar conductor 20. Furthermore, the connecting plate 40 forms a shorting wall, i.e. electrical current may flow from the planar conductor 20 to the ground plane 10 and vice versa with negligible ohmic resistance.

Subsequently, the particular arrangement of radiating and/or receiving elements on the ground plane shall be described. In Figure 1, an array of four radiating and/or receiving elements is shown. Each of said radiating and/or receiving elements is in itself identical. The position and orientation of the array of radiating and/or receiving elements is important for the properties of said antenna as a whole. An axis of symmetry 60 is shown in Figure 1. This axis is not a physical object but only a line of reference in order to describe precisely the arrangement of the radiating and/or receiving elements. Said axis 60 is oriented perpendicular to both the ground plane 10 and the planar conductors 20 of the radiating and/or receiving elements. The array 25 of radiating and/or receiving elements as a whole is a symmetrical arrangement with regard to the axis of symmetry 60. The array of radiating and/or receiving elements may be mapped onto itself by rotation of 90° around the axis of symmetry 60. Furthermore, each individual radiating and/or receiving element may be mapped onto a neighbouring radiating element by rotating said individual radiating and/or receiving element by integer multiples of 90° around the axis of symmetry 60. The plane conductors 20 of said array 25 of radiating and/or receiving elements all lie within the same flat plane parallel to the ground plane 10. They essentially form part of a square, wherein each rectangular plane conductor 20 is place into the corner of said square.

The concept of sequentially rotating 4 radiating and/or receiving elements and feeding the elements with a sequential 90° phase difference is used to create a circular polarized radiation pattern. The feeding network will be described later with reference to Figures 3 to 6.

Figure 2 displays a side view of the antenna of the preferred embodiment. Identical reference signs in Figures 1 and 2 denote the same features in Figures 1 and 2. In this depiction, the essentially two-dimensional planar conductors 20 merely appear as a line. The flat ground plane 10 forms the surface of a larger ground body 70. The ground body 70 comprises a annular cavity 80 i.e. an annular air space or insulator space. Its annular shape is generated by revolving a geometrical figure around an axis external to that figure. Said axis of symmetry is represented in Figure 2 by reference sign 85. Please note that this axis is merely a line of reference and does not denote a particular object. Furthermore, the axis of symmetry 85 of the annular cavity is identical with the axis of symmetry 60 for the array of radiating and/or receiving elements depicted in Figure 1. The annular cavity is formed within the ground body 70. The annular air space or insulator space is essentially formed in a plane perpendicular to the axis of symmetry 85. The annular space may include any suitable insulator such as air or a foamed polymer, etc. The planar conductors 20 and the annular cavity are arranged on opposite sides of the ground plane 10.

The annular cavity 80 within the ground body 70 can be embodied as a choke ring. A choke ring is basically a half wave-guide structure with a particular resonance frequency and a bandwidth. Choke rings have quite narrow frequency bands compared to a 30% bandwidth requirement. The suppression of transmitted radiation degrades when moving away from the resonance frequency of the annular cavity 80. Increasing the frequency means that the choke ring is electrically too large. However, this has a very useful side effect, namely improved circular polarization at low elevations. An electrically small choke ring does not have this effect. These 2 effects are being used in the annular cavity 80.

A (wideband) antenna mounted on a normal ground plane has an electrically smaller ground plane at the lower end of the frequency band and an electrically larger ground plane at the higher end of the frequency band. The array 25 of radiating and/or receiving elements has a good circular polarization at the lower end of the frequency band and a worse circular polarization at the higher end of the frequency band. The front-to-back ratio is better at the higher end of the frequency band because the ground plane is electrically larger. Thus, tuning the choke ring slightly below the lower end of the frequency band, results in improved front-to-back ratio, radiation pattern shape stability and circular polarization over the entire frequency band. The addition of the annular cavity, e.g. in the form of a horizontal choke ring makes the ground plane maintain its electrical size over a much wider frequency range relative to the frequency range covered by the same ground plane but without the annular cavity. This makes the displayed annular cavity, e.g. horizontal choke ring design unique.

The particular implementation of the ground body 70 in Figure 2 comprises three distinct features. Two discs 90 and 100 are separated by a conductive cylindrical body 110. An outer surface of disc 90 forms the second ground plane 20 of the antenna. The first disc 90 can be, if desired, considerably thicker than the second disc 100. The diameter of both discs 90 and 100 can be different.

The axis of symmetry 85 is symmetrical in relation to the annular cavity 80 as well as the discs 90 and 100 and the cylindrical body 110. The first disc 90 and the cylindrical body 110 each comprise a closed cavity for taking in electronic components.

The diameters and thicknesses of all components of ground body 70 are preferably tuned to fit the associated feed electronics, to create a support for a radome as well as optimum electromagnetic behaviour for the target application.

In order to generate circular polarized electromagnetic radiation with said antenna, the radiating and/or receiving elements must be fed with an appropriate signal. The input signal must be distributed to each radiating and/or receiving element, such that the radiating and/or receiving elements are excited with signals having a sequential 90° phase difference in relation to each other. Additionally, the feeding network must be adapted to provide these exciting signals across a large bandwidth in order to take advantage of the bandwidth of the antenna. Therefore, the problem shifts to designing a feeding network with the correct phase and magnitude behaviour. It is to be understood that even if the description mainly refers to transmit, the feeding network can be used in receive or in transmit.

The feed network operates as an electrical coupler between the radiating or receiving antenna elements of an antenna and external electronics and will be described with reference to Figures 3 and 4.

A 90° coupler is a device that is used to equally split an input signal into two output signal with a resultant 90° phase difference between output signals. This coupler may be described as a differential phase splitter. A 180° coupler is a device that is used to equally split an input signal into two output signal with a resultant 180° phase difference between output signals. This coupler may be described as a differential phase splitter.

Figure 3 shows a schematic block diagram of an embodiment of a feeding network 120, which may be used for receiving signals from or feeding signals to the radiating and/or receiving elements of the antenna according to the present invention. The feeding network when used in transmit mode has a single input 150a for receiving a signal, which is to be transmitted by the antenna. Four outputs 140a, 140b, 140c and 140d are also provided. Each of these outputs is connected to one radiating and/or receiving element via the feed probe. If a monochromatic signal is input to said electrical coupler, then the four outputs 140a to 140c each carry a signal with identical amplitude and the same frequency as the input signal. The four output signals are sequentially phase shifted by 90 degrees. The resulting phase shift is achieved by using two distinct phase shifters. A 180° coupler is arranged at the outputs 150b and 150c. These signals are phase shifted by 180°. The next stage of the electrical coupler comprises two identical 90° couplers, which are connected to the output 150b and 150c of the 180° coupler, respectively. Both 90° couplers divide the input signal into two equally strong signals with a 90° phase difference between them. Consequently, the four output signals from the two 90° couplers are each phase shifted by 90°, 180 or 270° with respect to each other.
Figure 4 shows a further implementation of feeding network for use in the present invention. Since both figure 3 and 4 comprises similar features, the same reference signs are used to depict the same features in figures 1 and 2. The structure of figure 4 is basically created by exchanging the 180° coupler of Figure 3 with a 90° coupler and replacing the 90° couplers of Figure 3 with 180° couplers. Otherwise the overall structure is identical. The 90° coupler generates two identical output signals, which are phase shifted by 90°. The signals on outputs 140b and 140c are merely exchanged in comparison with the embodiment of Figure 3.

The 90° coupler may be implemented by a quadrature coupler such as a branchline coupler also known as quadrature hybrid. For example, the branchline coupler may comprise four quarter wavelength transmission lines, which are connected to each other as to form a ring of transmission lines. A signal entering port 160a is split into two quadrature signals at ports 160b and 160c, with the remaining port well isolated from the input port within the operating frequency band. This arrangement yields an appropriate 90° phase difference across a reasonably wide frequency band. However, both circuits of Figures 3 and 4 additionally comprise a 180° coupler. Conventional 180° couplers do not provide a precise 180° phase difference across a reasonably wide frequency band. This is true in particular for rat race couplers.

Consequently, a novel 180° coupler is shown in Figure 5. This 180° coupler may be used in the coupling circuits of Figures 3 and 4. The 180° coupler of Figure 5 comprises an input 160a and two outputs 160b and 160c. The input signal is fed to a power splitter 170. The power splitter 170 outputs two identical signals with the same magnitude, frequency and phase. The amplitude of the output signal of the power splitter is half the amplitude of its input signal. Additionally, the 180° coupler of Figure 5 comprises two essentially identical 90° couplers These 90° couplers are quadrature hybrids 180a and 180b. The quadrature hybrids 180a and 180b differ only in that the quadrature hybrid 180a is adapted to shift the input signal by +90°, whereas the quadrature hybrid 180b is adapted to shift the input signal by -90°. For example, quadrature hybrids 180a and 180b can be identical and the impedance used to terminate them may be different. For example hybrid 180a is loaded with inductors 200 while 180b is loaded with capacitors 210. This results in turn in two output signals 160b and 160c, with a 180° phase difference. Since only broadband power splitter 170 and quadrature hybrids are employed, the resulting 180° phase difference is maintained over the same frequency band as quadrature hybrids. The quadrature hybrid 180a has a certain phase versus frequency variation (dispersion). A constant 180° phase difference between the 2 outputs 160b and 160c is desired, thus equal dispersion. This means that each output of 170 needs a phase shifter, e.g. one phase shifter 1 consists of 180a and 2 inductors 200, the other phase shifter consists of 180b and 2 capacitors 210..

In order to have a 180° phase difference the reactive loads 200 and 210 of the 2 quadrature hybrids need to be opposite in phase. Shorting or leaving the reflected outputs open is a possible implementation, but does not work very well because of an impedance mismatch and the hybrids can not be tuned to compensate for this impedance mismatch. Quadrature hybrid 180a is connected to two inductive loads 200, whereas quadrature hybrid 180b is connected to two capacitive loads 210. Therefore, the output phase of the respective quadrature hybrids 180a and 180b have a 180° phase difference. The magnitude of the impedance of the capacitive load is equal to the magnitude of the impedance of the inductive load and the phase of the impedance of the capacitive load is opposite to the phase of the impedance of the inductive load. The best wideband implementation is based on lumped element reactive loads because of their frequency less variant behaviour. In analogy with the short/open, one phase shifter needs capacitors while the other one needs inductors at the outputs. Reflection occurs at the inductors and capacitors. This results in the correct phase behaviour over the entire hybrid bandwidth.

To provide a 180° splitter a first device for phase shifting one of the two output signals from the power splitter and a second device for phase shifting the other of the two output signals from the power splitter can be provided whereby the total phase difference between the one output signal and the other output signal is 180°. Hence it is not necessary to always have exactly plus or minus 90° phase shift on the outputs provided the difference is 180°.

The following equations can be derived for a 180° phase difference between the outputs 160b and 160c:

$$Z_0 = \frac{1}{2\pi f C} \qquad \text{Eq1}$$

$$Z_0 = 2\pi f_I L \qquad \text{Eq2}$$

Z is the characteristic impedance magnitude of the capacitor and the inductor and is equal to the system impedance, usually 50 Ω.

The equations can be rearranged to:

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad \text{Eq3}$$

$$Z_0 = \sqrt{\frac{L}{C}} \qquad \text{Eq4}$$

Figure 6 shows another implementation of a 180° coupler for use in the electrical couplers according to Figures 3 and 4. The implementation and functioning of said 180° coupler largely corresponds to the way it is implemented in the embodiment of Figure 5. Therefore, identical reference signs depict identical features in figures 5 and 6. The 180° coupler of Figure 6 differs from 180° coupler of Figure 5 in that the quadrature hybrid couplers have been replaced by circulators. Furthermore, the circulators are three port devices, such that only a single reactive load is connected to the respective circulators. The appropriate choice of reactive loads is determined in the same way as in the case of the 180° coupler of figure 5.

Claims

1. An antenna for radiating electromagnetic waves, in particular radio waves or microwaves, said antenna comprising:
a ground body (70)having a first ground plane (10),
four radiating and/or receiving elements (20) arranged in array whereby each radiating and/or receiving element is rotated 90° about an axis perpendicular to the plane of the first ground plane (10), and
each radiating and/or receiving element (20) comprising a planar conductor (20), wherein the planar conductor (20) is arranged in parallel to the first ground plane (10),
wherein an L-shaped slot (30) is arranged in each said planar conductor (20).

2. Antenna for radiating electromagnetic waves according to claim 1, wherein each said radiating and/or receiving element comprises a connector (40) for connecting the planar conductor (20) to the first ground plane (10), wherein the connector (40) is arranged perpendicular to both the first ground plane (10) and the planar conductor (20).

3. Antenna according to claim 2, wherein the connector (40) is a connecting plate or conductive post or a linear array of conductive posts.

4. Antenna for radiating electromagnetic waves according to any previous claim 1, wherein each said radiating and/or receiving element comprises a feed probe (50), said probe (50) being connected to the planar conductor (20) and having a port for connection to a feeding network.

5. Antenna for radiating electromagnetic waves according to any previous claim, the four said radiating and/or receiving elements, are arranged around an axis of symmetry (60, 85) perpendicular to the first ground plane (10) in such a way that each one of said radiating and/or receiving elements may be mapped onto an adjacent one of said radiating and/or receiving elements by rotating said one

radiating and/or receiving element by integer multiples of 90° around the axis of symmetry (60, 85).

6. Antenna for radiating electromagnetic waves according to any previous claim,

wherein the ground body has first and second ground planes that form a surface of the ground body and an annular cavity (80), and

wherein an axis of symmetry (60, 85) of said annular cavity (80) is perpendicular to the first ground plane (10).

7. Antenna for radiating electromagnetic waves according to claims 5 or 6, wherein the axis of symmetry (60, 85) of the radiating and/or receiving elements is the axis of symmetry (60, 85) of the annular cavity (80).

8. Antenna for radiating electromagnetic waves according to claims 6 or 7, wherein the ground body (70) comprises a first disc (90), a second disc (100) and a cylindrical body (110), wherein the first and second disks are arranged in parallel to each other and the cylindrical body (110) is arranged between the first and second disk, such that the annular cavity (80) encompasses the cylindrical body (110).

9. Antenna for radiating electromagnetic waves according to claim 8, wherein the first disc (90), the second disc (100) and/or the cylindrical body (110) encompass a closed cavity for taking in electronic components.

10. Antenna for radiating electromagnetic waves according to claim 8 or 9, wherein the thickness of the first disk is greater than the thickness of the second disk.

11. Antenna for radiating electromagnetic waves according to one of the claims 5 to 10, comprising

a feeding network(120) for connecting said radiating and/or receiving elements (20) to each other, said feeding network (120) comprising one input and a first, second, third and fourth output, each of said outputs being connected to one of said radiating and/or receiving elements via the feed probe (50) of each radiating and/or receiving element, said feeding network (120) being adapted to generate a first, second, third and fourth output signals from a single input signal at the first, second, third and fourth output, respectively, wherein the first output signal is phase shifted by 90° in relation to the second output signal, by 180° in relation to the third output signal and by 270° in relation to the fourth output signal.

12. Antenna for radiating electromagnetic waves according to claim 11, wherein the feeding network (120) comprises:

one 180° coupler having a 180° coupler input and two 180° coupler outputs; wherein the 180° coupler input is connected to the input of said electrical coupler (120); and

two 90° couplers each having a 90° coupler input and two 90° coupler outputs, the 90° couplers outputs of said two 90° couplers forming the first, second, third and fourth output of the electrical coupler (120);

wherein each 90° coupler input is connected to one of said two 180° coupler outputs.

13. Antenna for radiating electromagnetic waves according to claim 11, wherein the feeding network(120) comprises:

one 90° coupler having a 90° coupler input and two 90° coupler outputs; wherein the 90° coupler input is connected to the input of said electrical coupler (120); and

two 180° couplers each having a 180° coupler input and two 180° coupler outputs, the 180° coupler outputs of said two 180° couplers forming the first, second, third and fourth output of the electrical coupler (120);

wherein each 180° coupler input is connected to one of said two 90° coupler outputs.

14. Antenna for radiating electromagnetic waves according to claims 12 or 13, wherein said 180° coupler comprises:

a first device for phase shifting one of the two output signals from the power splitter and

a second device for phase shifting the other of the two output signals from the power splitter and whereby the total phase difference between the one output signal and the other output signal is 180°.

15. Antenna for radiating electromagnetic waves according to claim 14, wherein the first device comprises a 90° hybrid coupler, said 90° hybrid coupler having an 90° hybrid coupler input, two 90° hybrid coupler outputs and an isolated port, said isolated port forming the output of the first device, wherein the two 90° hybrid coupler outputs are each connected to an inductive load.

16. Antenna for radiating electromagnetic waves according to claims 14 or 15, wherein the second device comprises a 90° hybrid coupler, said 90° hybrid coupler having an 90° hybrid coupler input, two 90° hybrid coupler outputs and an isolated port, said isolated port forming the output of the second device, wherein the two 90° hybrid coupler outputs of the second device are each connected to a capacitive load.

17. Antenna for radiating electromagnetic waves according to claim 14, wherein the first device is a circulator, said circulator having a circulator input port, a circulator output port and a circulator isolated port, said circulator isolated port forming the output of the first device, wherein the circulator output port is connected to an inductive load.

18. Antenna for radiating electromagnetic waves according to any of the claims 15 to 17, wherein the second device is a circulator, said circulator having a circulator input port, a circulator output port and a circulator isolated port, said circulator isolated port forming the output of the second device, wherein the circulator output port is connected to a capacitive load.

19. Antenna for radiating electromagnetic waves according to claims 15, 16, 17,

or 18, wherein the magnitude of the impedance of said capacitive load is equal to the magnitude of the impedance of said inductive load and the phase of the impedance of said capacitive load is opposite to the phase of the impedance of said inductive load.

20. Antenna according to any of the previous claims wherein each radiating and/or receiving element is configured as a Planar Inverted F Antenna.

21. A feeding network for connecting to radiating and/or receiving elements of an antenna to each other, said feeding network (120) comprising one input and a first, second, third and fourth output, each of said outputs being connected to one of said radiating and/or receiving elements via a feed probe (50) of each radiating and/or receiving element, said electrical coupler (120) being adapted to generate a first, second, third and fourth output signals from a single input signal at the first, second, third and fourth output, respectively, wherein the first output signal is phase shifted by 90° in relation to the second output signal, by 180° in relation to the third output signal and by 270° in relation to the fourth output signal.

22. Feeding network (120) according to claim 21, further comprising:

one 180° coupler having a 180° coupler input and two 180° coupler outputs; wherein the 180° coupler input is connected to the input of said electrical coupler (120); and

two 90° coupler each having a 90° coupler input and two 90° coupler outputs, the 90° coupler outputs of said two 90° couplers forming the first, second, third and fourth output of the electrical coupler (120);

wherein each 90° coupler input is connected to one of said two 180° coupler outputs.

23. Feeding network (120) according to claim 21 further comprising:

one 90° coupler having a 90° coupler input and two 90° coupler outputs; wherein the 90° coupler input is connected to the input of said electrical coupler (120); and two 180° couplers each having a 180° coupler input and two 180° coupler outputs, the 180° coupler outputs of said two 180° couplers forming the first, second, third and fourth output of the electrical coupler (120);

wherein each 180° coupler input is connected to one of said two 90° coupler outputs.

24. Feeding network according to claims 22 or 23, wherein said 180° coupler comprises:

a power splitter for splitting the input signal of the 180° coupler into two in phase signals of equal power;

a first device for phase shifting one of the two output signals from the power splitter and

a second device for phase shifting the other of the two output signals from the power splitter and

whereby the total phase difference between the one output signal and the other output signal is 180°

25. Feeding network according to claim 24, wherein the first device comprises a 90° hybrid coupler, said 90° hybrid coupler having an 90° hybrid coupler input, two 90° hybrid coupler outputs and a 90° hybrid coupler isolated port, said 90° hybrid coupler isolated port forming the output of the first device, wherein the two 90° hybrid coupler outputs are each connected to an inductive load.

26. Feeding network according to claims 24 or 25, wherein the second device comprises a 90° hybrid coupler, said 90° hybrid coupler having an 90° hybrid coupler input, two 90° hybrid coupler outputs and a 90° hybrid coupler isolated port, said 90° hybrid coupler isolated port forming the output of the second device, wherein the two 90° hybrid coupler outputs of the second device are each connected to a capacitive load.

27. Feeding network according to claim 24, wherein the first device is a circulator, said circulator having a circulator input, a circulator output and a

circulator isolated port, said circulator isolated port forming the output of the second device, wherein the circulator output port is connected to an inductive load.

28. Feeding network according to any of claims 24 or 27, wherein the second device is a circulator, said circulator having a circulator input, a circulator output and a circulator isolated port, said circulator isolated port forming the output of the second device, wherein the circulator output port is connected to a capacitive load.

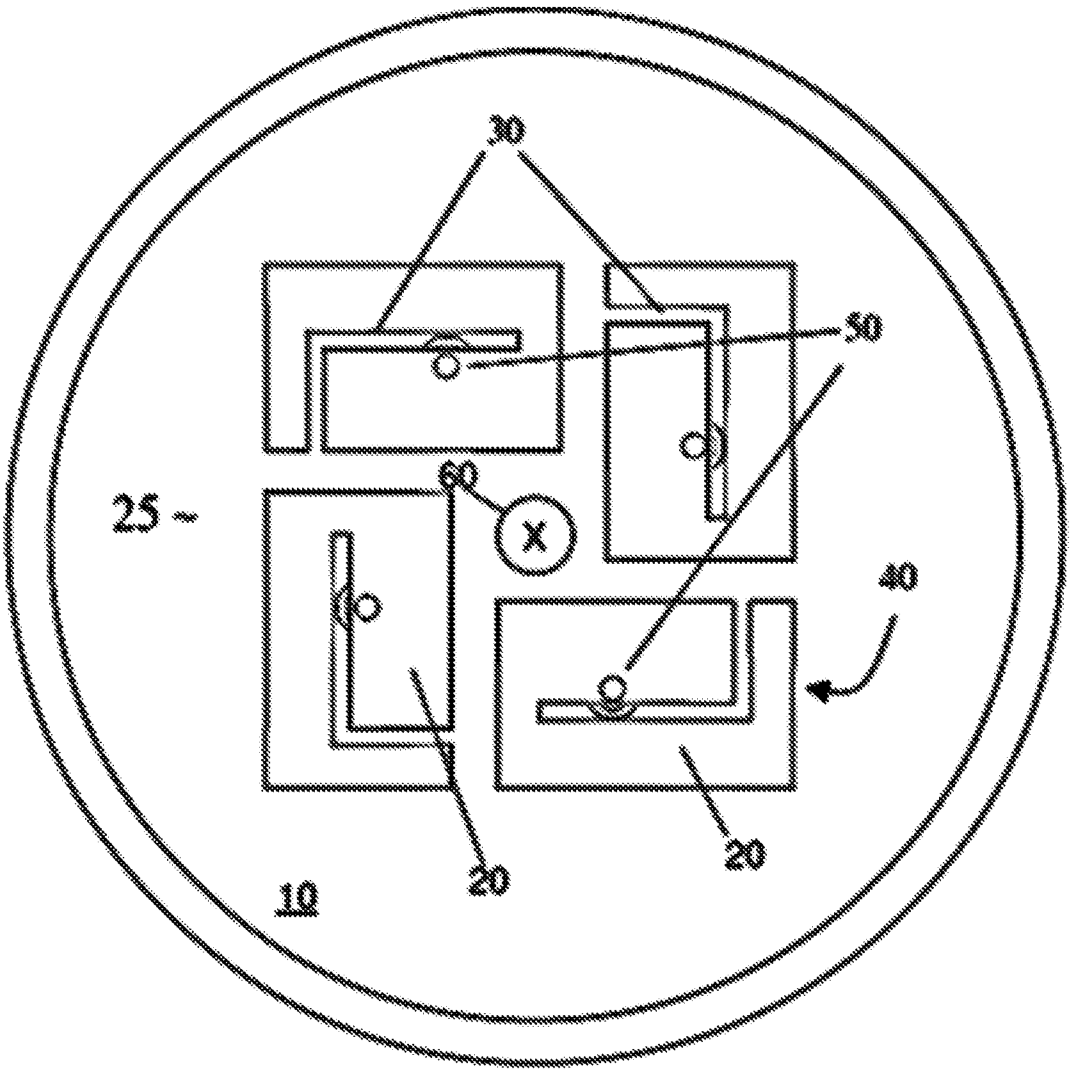


Fig. 1

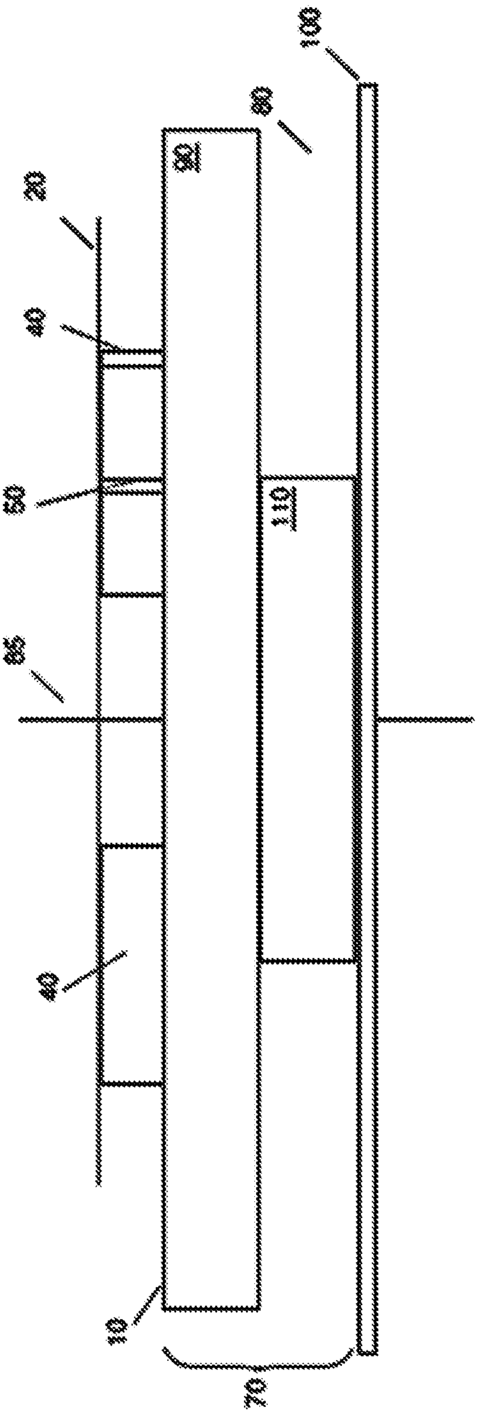
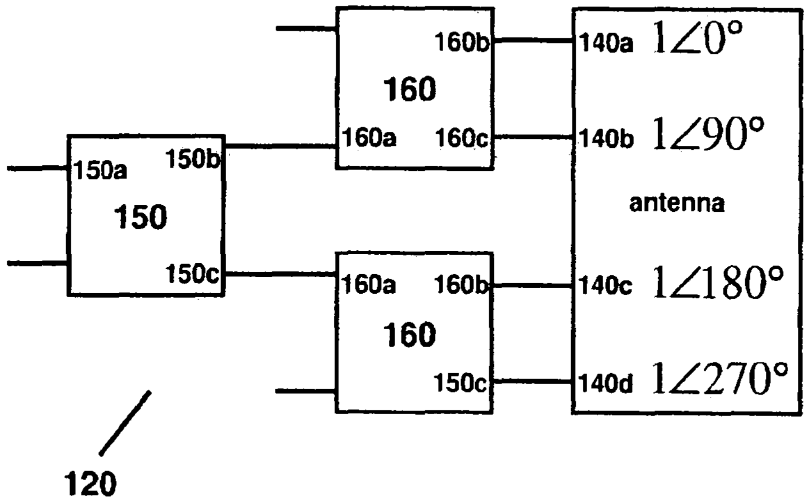


Fig. 2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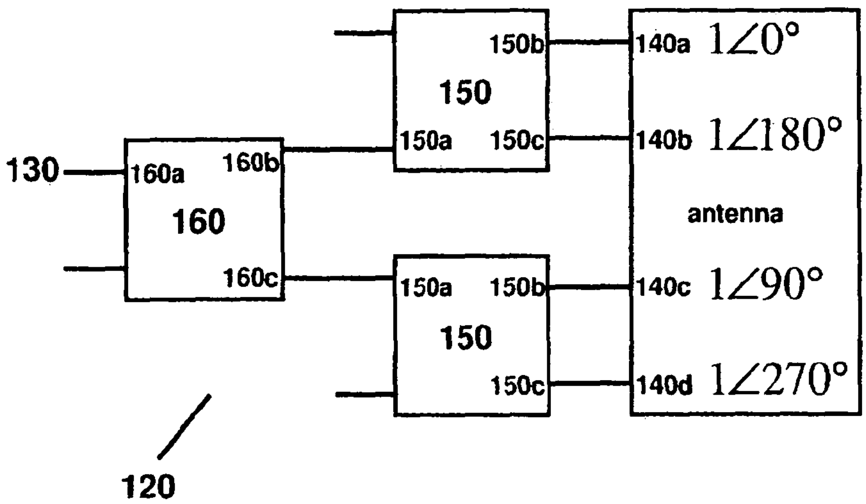
160a
160c
140a $1\angle 0°$
140b $1\angle 90°$
antenna
150a
150b
150
150c
160a
160b
160
150c
140c $1\angle 180°$
140d $1\angle 270°$
120

Fig. 3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120

Fig. 4

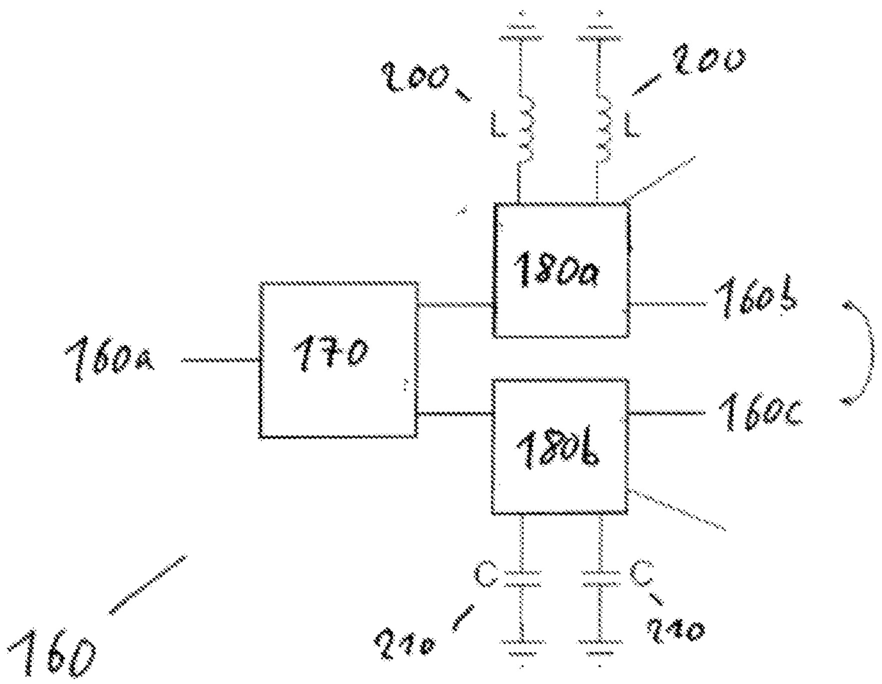

Fig. 5

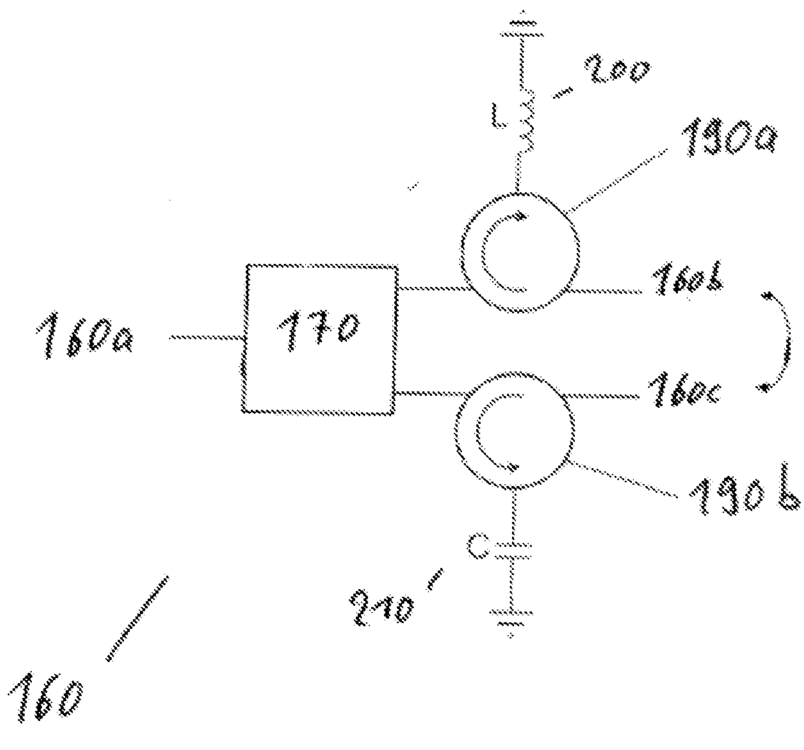

Fig. 6