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UTILITY PATENT APPLICATION TRANSMITTAL

(ONLY FOR NEW NONPROVISIONAL APPLICATIONS UNDER 37 CFR 1.53(B))

Attorney Docket No.	47005-P040WUSC1
First Inventor	Josep Mumbru
Title	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. [ ] **Fee Transmittal Form** (e.g., PTO/SB/17)
2. [ ] **Applicant claims small entity status.** See 37 CFR 1.27.
3. [X] **Specification** [*Total Pages* 54]
   Both the claims and abstract must start on a new page
   (For information on the preferred arrangement, see MPEP 608.01(a))
4. [X] **Drawing(s)** *(35 U.S.C. 113)* [*Total Sheets* 23]
5. **Oath or Declaration** [*Total Sheets* 4]
   a. [ ] Newly executed (original or copy)
   b. [X] A copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 18 completed)*
      i. [ ] DELETION OF INVENTOR(S)
      Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. [ ] **Application Data Sheet**. See 37 CFR 1.76
7. [ ] **CD-ROM or CD-R** in duplicate, large table or Computer Program *(Appendix)*
   [ ] Landscape Table on CD
8. **Nucleotide and/or Amino Acid Sequence Submission** *(if applicable, items a. – c. are required)*
   a. [ ] Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
      i. [ ] CD-ROM or CD-R (2 copies); or ii. [ ] Paper
   c. [ ] Statements verifying identity of above copies

ADDRESS TO: **Commissioner for Patents**
P.O. Box 1450
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ACCOMPANYING APPLICATION PARTS

9. [ ] **Assignment Papers** (cover sheet & document(s))
   Name of Assignee
10. [ ] **37 CFR 3.73(b) Statement** *(when there is an assignee)* [ ] **Power of Attorney**
11. [ ] **English Translation Document** *(if applicable)*
12. [ ] **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
    [ ] Copies of citations attached
13. [X] **Preliminary Amendment**
14. [ ] **Return Receipt Postcard** (MPEP 503) *(Should be specifically itemized)*
15. [ ] **Certified Copy of Priority Document(s)** *(if foreign priority is claimed)*
16. [ ] **Nonpublication Request** under 35 U.S.C.122 (b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
17. [ ] Other:

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*
    [X] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No.: 11/988,888
    Prior application information: Examiner Hoang V. Nguyen *Art Unit:* 2821

19. CORRESPONDENCE ADDRESS

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Signature	/Shoaib A. Mithani/	Date	December 30, 2011
Name (Print/Type)	Shoaib A. Mithani	Registration No. (Attorney/Agent)	61,654

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Dated: December 30, 2011 Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

5784253v.1 47005/P040WUSC1

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
First Named Inventor/Applicant Name:	Josep Mumbru
Filer:	Shoaib Amirali Mithani
Attorney Docket Number:	47005-P040WUSC1

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility application filing	1011	1	380	380
Utility Search Fee	1111	1	620	620
Utility Examination Fee	1311	1	250	250
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1250**

Electronic Acknowledgement Receipt	
EFS ID:	11736178
Application Number:	13341051
International Application Number:	
Confirmation Number:	9540
Title of Invention:	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
First Named Inventor/Applicant Name:	Josep Mumbru
Customer Number:	61060
Filer:	Shoaib Amirali Mithani
Filer Authorized By:	
Attorney Docket Number:	47005-P040WUSC1
Receipt Date:	30-DEC-2011
Filing Date:	
Time Stamp:	13:18:19
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$1250
RAM confirmation Number	588
Deposit Account	232426
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Preliminary Amendment	Amendment.pdf	22593 920f736cb0012f1ec7ed7eed40c945ba1fb63cba	no	3
Warnings:					
Information:					
2		Application.pdf	1754406 1b2ff1f87015cc83eef66ac94d427c72963a8e5d	yes	75

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	46
Claims	47	51
Abstract	52	52
Drawings-only black and white line drawings	53	75

Warnings:					
Information:					
3	Oath or Declaration filed	Declaration.pdf	76151 86cd77fe81477bd2fe42dee33e417fba65144007	no	4
Warnings:					
Information:					
4	Transmittal of New Application	Transmittal.pdf	37676 45f3b4e226f55810aec8b2b91760523a93a10aaa	no	1
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	33200 f9f42b95805e2aad4c529d4e6fabdd1a20edd769	no	2
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New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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Dated: December 30, 2011
Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

Docket No. 47005-P040WUSC1
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Josep Mumbru et al.

Application No. Not Yet Assigned

Confirmation No. N/A

Filed: Concurrently Herewith

Art Unit: N/A

For: HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS

Examiner: Not Yet Assigned

FIRST PRELIMINARY AMENDMENT

MS Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

INTRODUCTORY COMMENTS

Prior to examination on the merits, please amend the above-identified U.S. patent application as follows:

Amendments to the Specification begin on page 2 of this paper.

Remarks/Arguments begin on page 3 of this paper.

AMENDMENTS TO THE SPECIFICATION

Please add the following on page 1 of the specification after the title of the invention:

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application is a continuation application of U.S. Patent Application No. 11/988,888. U.S. Patent Application No. 11/988,888 is a national-stage filing of International Patent Application No. PCT/EP2006/007050. International Patent Application No. PCT/EP2006/007050 was filed on July 18, 2006. International Patent Application No. PCT/EP2006/007050 claims priority from European Patent Application EP 05106694.2, which was filed on July 21, 2005. International Patent Application No. PCT/EP2006/007050 claims priority from U.S. Provisional Patent Application No. 60/702,205, filed on July 25, 2005. U.S. Patent Application No. 11/988,888, U.S. Provisional Patent Application No. 60/702,205, International Patent Application No. PCT/ EP2006/007050, and EP 05106694.2 are incorporated herein by reference.

REMARKS

It is submitted that no new matter has been added by the amendments made by this preliminary amendment. Early consideration of the application as amended is respectfully requested.

Dated: December 30, 2011

Respectfully submitted,

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HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS

Object of the invention

The present invention relates to a handset and generally to any handheld device, which includes an antenna for receiving and transmitting electromagnetic wave signals.

It is an object of the present invention to provide a handset or handheld device (such as, for instance, a mobile phone, a smartphone, a PDA, an MP3 player, a headset, a USB dongle, a laptop, a PCMCIA or Cardbus 32 card), which comprises a first antenna (for example, an antenna for mobile communications), and a second antenna (for mobile communications, and/or for at least one wireless connectivity service), said second antenna being a slot antenna. The second antenna can require a very small area on the printed circuit board (PCB) of the hand-held device.

Another aspect of the invention relates to a technique to obtain good isolation between said first antenna and said second antenna. According to the present invention, good isolation between the antennas included in the handset or handheld device can be obtained by appropriately choosing the placement and orientation on the PCB of each one of the antennas comprised in the handset or handheld device, and/or by acting on the PCB (or, rather, on a conductive layer of the PCB, such as a metal layer of the PCB acting as a ground-plane for one or both of the antennas) of the handset or handheld device to reduce the electromagnetic coupling between antennas, and/or by other means

Background of the invention

The current trend in the sector of mobile phone manufacturers, and more generally handheld device manufacturers, is to incorporate added value wireless services, such as connectivity functionality and geolocalization (such as for example, but not limited to Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB) in more and more of their products. An antenna arranged or configured to operate effectively in a frequency band suitable for one or more of these services or standards is sometimes referred to as a "wireless connectivity antenna" in this document.

In some cases, these handheld devices also operate in at least one frequency band used for mobile communication services, such as GSM (GSM850, GSM900, GSM1800, American GSM or PCS1900, GSM450), UMTS, WCDMA, or CDMA, apart from having the ability to operate in the frequency band corresponding to the wireless connectivity service.

Although it is possible to integrate all the operating bands of a particular handheld device in a single antenna, the trend in the handset manufacturing industry shows that it is preferred to have two separate antennas: A first antenna is used for the bands of the selected mobile communication services (such as, for example, GSM), and a second antenna is used to allow the device to operate at an additional communication service (such as, for instance, UMTS) or at the frequency bands of a wireless connectivity standard (such as, for example, WLAN or Bluetooth™).

Using two separate antennas presents some advantages:

- It can make the design of each one of the antennas easier, as a single multiband antenna covering all the bands of operation of the handset would require a more complicated design.

- It also simplifies the radiofrequency (RF) front-end for each one of the two antennas. If there is only one single antenna, the RF front-end to which the antenna is connected would have to include a diplexer or multiplexer capable of separating the frequency bands corresponding to the different services, for example, separating the mobile communication frequency bands from the wireless connectivity frequency bands.

- Moreover, it offers more flexibility in the design of the PCB that carries the electronic components and circuitry of the handset or handheld device. In many cases, a PCB designer will preferably lay out the module or chipset providing the wireless connectivity functionality, and the module or chipset for the mobile communication services, in different parts of the PCB.

The first antenna can typically be, for instance and without limitation, a monopole antenna, an inverted-F antenna (IFA), a patch antenna, or a planar inverted-F antenna (PIFA). Some known solutions for said second antenna include antennas printed on the PCB of the device (such as, for example, but not limited to, a printed IFA), or an antenna component, or a chip antenna.

However, the integration in a handset of a second antenna dedicated to the wireless connectivity services is not trivial. As the space available on the PCB of the device is scarce, antenna solutions with small footprints are advantageous. Printed antennas are typically not small in size, since their dimensions are approximately a quarter of an operating wavelength of the antenna. Chip antennas may achieve some degree of miniaturization (for instance, by loading the antenna with a material with high dielectric constant), however, in many cases, they exhibit poor matching levels, and limited bandwidth, efficiency and/or gain.

One additional problem that further complicates the integration of the wireless connectivity antenna in a handset or handheld device is the low isolation that is usually obtained between this antenna and the antenna used for mobile communications.

Interband isolation can be improved by separating the two antennas further apart, although this might not be practical in typical handsets due to their small size and due to the limited positions that are available to integrate the wireless connectivity antenna. This is the case especially for more recent handset topologies, like for example flip-type (also known as clamshell) phones and slider-type phones (as the one schematically illustrated in Figure 1). As an alternative, a filter can be used to achieve the required level of isolation between antennas within the operating bands. However, this approach implies adding extra components on the PCB, thus using up more space on the PCB of the device, and resulting in an increase in cost of the handset.

A conventional handset that includes an antenna for mobile communications and an antenna for wireless connectivity is depicted in Figure 2. For this example, the handset has been selected to have a slider-type topology as schematically illustrated in Figure 1. A slider-type handset comprises typically a first PCB (100) placed substantially above and parallel to a second PCB (102). The first PCB (100) has the ability to slide above the second PCB (102), so that the handset can be in a closed position, as shown in Figure 1(a) or in an open position, as shown in Figure 1(b). Generally, the first PCB (100) and the second PCB (102) are electrically connected, for example by means of a flexible conductive film (not illustrated in figure 1). An antenna 101 is mounted at one end of the first PCB. In this case, the antenna is a Planar Inverted-F Antenna (PIFA), with a short-circuit (101B) to the ground-plane (in this case, to a conductive metal layer of the PCB) and with a feeding point (101A) close to said short-circuit.

For the purpose of the example illustrated in Figure 2, the handset comprises a first antenna (201), placed on the top part of the first PCB (200), that operates at the frequency bands for mobile communications, and a second antenna (202) placed on the bottom right corner of the PCB (200) that operates at the frequency bands of the wireless connectivity services. The first antenna has a feeding point (201A) and a short-circuit (201B) to ground (namely, to a conductive metal layer of the PCB 200, constituting a ground-plane for the antenna). For illustrative purposes, in the example illustrated in figure 2, the second antenna (202) is a surface mount technology (SMT) component mounted on the PCB (200), although it could have been replaced by, for example, an antenna printed on the PCB (200).

Some typical electrical results for the handset of Figure 2 are shown without any limiting purpose in Figure 3. Figure 3a presents typical results of the input parameters of the antennas (i.e., return losses of each antenna, and isolation between antennas) when the slider-type phone is in the closed position, while Figure 3b presents the typical results of the antennas when the phone is in the open position. In this example, the first antenna (201) was designed to have a multiband behavior, with a first resonance around 900MHz to provide coverage for the GSM900 service, and a second resonance around 1900MHz to provide service to the GSM1800 and GSM1900 services. On the other hand, the second antenna was designed to be tuned in the 2500MHz band. These frequency ranges have been selected just to illustrate the example, but the antennas could work in any frequency band included in the range from approximately 400MHz to approximately 12GHz, including any subinterval. The isolation between the first antenna (201) and the second antenna (202) is 20dB in the 900MHz band, 18dB in the 1900MHz band. The isolation degrades to 17dB at the center of the resonance of the second antenna around 2600MHz.

Space Filling Curves

In some embodiments of the invention, at least one antenna of the antennas included in the handset or handheld device may be miniaturized by shaping at least a portion of the conducting trace, conducting wire or contour of a conducting sheet of the antenna (e.g., a part of the arms of a dipole, the perimeter of the patch of a patch antenna, the slot in a slot antenna, the loop perimeter in a loop antenna, or other portions of the antenna) as a space-filling curve (SFC).

An SFC is a curve that is large in terms of physical length but small in terms of the area in which the curve can be included. More precisely, for the purposes of this patent document, an SFC is defined as follows: a curve having at least five segments, or identifiable sections, that are connected in such a way that each segment forms an angle with any adjacent segments, such that no pair of adjacent segments defines a larger straight segment. In addition, an SFC does not intersect with itself at any point except possibly the initial and final point (that is, the whole curve can be arranged as a closed curve or loop, but none of the lesser parts of the curve form a closed curve or loop).

A space-filling curve can be fitted over a flat or curved surface, and due to the angles between segments, the physical length of the curve is larger than that of any straight line that can be fitted in the same area (surface) as the space-filling curve. Additionally, to shape the structure of a miniature antenna, the segments of the SFCs should be shorter than at least one fifth of the free-space operating wavelength, and possibly shorter than one tenth of the free-space operating wavelength. The space-filling curve should include at least five segments in order to provide some antenna size reduction, however a larger number of segments may be used. In general, the larger the number of segments and the narrower the angles between them, the smaller the size of the final antenna.

Box-Counting Curves

In other embodiments of the invention, at least one antenna of the antennas included in the handset or handheld device may be miniaturized by shaping at least a portion of the conducting trace, conducting wire or contour of a conducting sheet of the antenna to have a selected box-counting dimension.

For a given geometry lying on a surface, the box-counting dimension is computed as follows. First, a grid with substantially square identical cells or boxes of size L1 is placed over the geometry, such that the grid completely covers the geometry, that is, no part of the curve is out of the grid. The number of boxes N1 that include at least a point of the geometry are then counted. Second, a grid with boxes of size L2 (L2 being smaller than L1) is also placed over the geometry, such that the grid completely covers the geometry, and the number of boxes N2 that include at least a point of the geometry are counted. The box-counting dimension D is then computed as:

$$D = -\frac{\log(N2) - \log(N1)}{\log(L2) - \log(L1)}$$

For the purposes of the antennas included in the handset or handheld device described herein, the box-counting dimension may be computed by placing the first and second grids inside a minimum rectangular area enclosing the conducting trace, conducting wire or contour of a conducting sheet of the antenna and applying the above algorithm. The first grid should be chosen such that the rectangular area is meshed in an array of at least 5 x 5 boxes or cells, and the second grid should be chosen such that L2 = 1/2 L and such that the second grid includes at least 10 x 10 boxes. The minimum rectangular area is an area in which there is not an entire row or column on the perimeter of the grid that does not contain any piece of the curve.

The desired box-counting dimension for the curve may be selected to achieve a desired amount of miniaturization. The box-counting dimension should be larger than 1.1 in order to achieve a substantial antenna size reduction. If a larger degree of miniaturization is desired, then a larger box-counting dimension may be selected, such as a box-counting dimension ranging from 1.5 to 3. For the purposes of this patent document, curves in which at least a portion of the geometry of the curve has a box-counting dimension larger than 1.1 are referred to as box-counting curves.

For very small antennas, for example antennas that fit within a rectangle the longest side of which does not exceed one-twentieth the longest free-space operating wavelength of the antenna, the box-counting dimension may be computed using a finer grid. In such a case, the first grid may include a mesh of 10 x 10 equal cells, and the second grid may include a mesh of 20 x 20 equal cells. The box-counting dimension (D) may then be calculated using the above equation.

In general, for a given resonant frequency of the antenna, the larger the box-counting dimension, the higher the degree of miniaturization that will be achieved by the antenna. One way to enhance the miniaturization capabilities of the antenna is to arrange the several segments of the curve of the antenna pattern in such a way that the curve intersects at least one point of at least 14 boxes of the first grid with 5 x 5 boxes or cells enclosing the curve. If a higher degree of miniaturization is desired, then the curve may be arranged to cross at least one of the boxes twice within the 5 x 5 grid, that is, the curve may include two non-adjacent portions inside at least one of the cells or boxes of the grid.

Figure 17 illustrates an example of how the box-counting dimension of a curve (1700) is calculated. The example curve (1700) is placed under a 5 x 5 grid (1701) and under a 10 x 10 grid (1702). As illustrated, the curve (1700) touches N1=25 boxes in the 5 x 5 grid (1701) and touches N2=78 boxes in the 10 x 10

grid (1702). In this case, the size of the boxes in the 5 x 5 grid (1701) is twice the size of the boxes in the 10 x 10 grid (1702). By applying the above equation, the box-counting dimension of the example curve (1700) may be calculated as D=1.6415. In addition, further miniaturization is achieved in this example because the curve (1700) crosses more than 14 of the 25 boxes in grid (1701), and also crosses at least one box twice, that is, at least one box contains two non-adjacent segments of the curve. More specifically, the curve (1700) in the illustrated example crosses twice in 13 boxes out of the 25 boxes.

Grid Dimension Curves

In some embodiments of the invention, at least one antenna of the antennas included in the handset or handheld device may be miniaturized by shaping at least a portion of the conducting trace, conducting wire or contour of a conducting sheet of the antenna to include a grid dimension curve.

For a given geometry lying on a planar or curved surface, the grid dimension of curve may be calculated as follows. First, a grid with substantially identical cells of size L1 is placed over the geometry of the curve, such that the grid completely covers the geometry, and the number of cells N1 that include at least a point of the geometry are counted. Second, a grid with cells of size L2 (L2 being smaller than L1) is also placed over the geometry, such that the grid completely covers the geometry, and the number of cells N2 that include at least a point of the geometry are counted again. The grid dimension D (sometimes also referred to as D_g) is then computed as:

$$D = -\frac{\log(N2) - \log(N1)}{\log(L2) - \log(L1)}$$

For the purposes of the antennas included in the handset or handheld device described herein, the grid dimension may be calculated by placing the first and

second grids inside the minimum rectangular area enclosing the curve of the antenna and applying the above algorithm. The minimum rectangular area is an area in which there is not an entire row or column on the perimeter of the grid that does not contain any piece of the curve.

The first grid may, for example, be chosen such that the rectangular area is meshed in an array of at least 25 substantially equal cells. The second grid may, for example, be chosen such that each cell of the first grid is divided in 4 equal cells, such that the size of the new cells is L2 = ½ L1, and the second grid includes at least 100 cells.

The desired grid dimension for the curve may be selected to achieve a desired amount of miniaturization. The grid dimension should be larger than 1 in order to achieve some antenna size reduction. If a larger degree of miniaturization is desired, then a larger grid dimension may be selected, such as a grid dimension ranging from 1.5 - 3 (e.g., in case of volumetric structures). In some examples, a curve having a grid dimension of about 2 may be desired. For the purposes of this patent document, a curve having a grid dimension larger than 1 is referred to as a grid dimension curve.

In general, for a given resonant frequency of the antenna, the larger the grid dimension, the higher the degree of miniaturization that will be achieved by the antenna. One example way of enhancing the miniaturization capabilities of the antenna is to arrange the several segments of the curve of the antenna pattern in such a way that the curve intersects at least one point of at least 50% of the cells of the first grid with at least 25 cells enclosing the curve. In another example, a high degree of miniaturization may be achieved by arranging the antenna such that the curve crosses at least one of the cells twice within the 25-cell grid, that is, the curve includes two non-adjacent portions inside at least one of the cells or cells of the grid.

Figure 18 shows an example of a two-dimensional antenna forming a grid dimension curve 1800 with a grid dimension of approximately two. Fig. 19 shows the antenna of Figure 18 enclosed in a first grid 1900 having thirty-two (32) square cells, each with a length L1. Figure 20 shows the same antenna enclosed in a second grid 2000 having one hundred twenty-eight (128) square cells, each with a length L2. The length (L1) of each square cell in the first grid is twice the length (L2) of each square cell in the second grid (L1 = 2 x L2). An examination of Figure 19 and Figure 20 reveals that at least a portion of the antenna is enclosed within every square cell in both the first and second grids. Therefore, the value of N1 in the above grid dimension (D, sometimes also referred to as D_g) equation is thirty-two (32) (i.e., the total number of cells in the first grid), and the value of N2 is one hundred twenty-eight (128) (i.e., the total number of cells in the second grid). Using the above equation, the grid dimension of the antenna may be calculated as follows:

$$D_g = -\frac{\log(128) - \log(32)}{\log(2 \times L1) - \log(L1)} = 2$$

For a more accurate calculation of the grid dimension, the number of square cells may be increased up to a maximum amount. The maximum number of cells in a grid is dependent upon the resolution of the curve. As the number of cells approaches the maximum, the grid dimension calculation becomes more accurate. If a grid having more than the maximum number of cells is selected, however, then the accuracy of the grid dimension calculation begins to decrease. Typically, the maximum number of cells in a grid is one thousand (1000).

For example, Fig. 21 shows the same antenna as that of Fig. 18 enclosed in a third grid 2100 with five hundred twelve (512) square cells, each having a length L3. The length (L3) of the cells in the third grid is one half the length (L2) of the cells in the second grid, shown in Fig.20. As noted above, a portion of the antenna is enclosed within every square cell in the second grid, thus the value

of N for the second grid is one hundred twenty-eight (128). An examination of Fig. 21, however, reveals that the antenna is enclosed within only five hundred nine (509) of the five hundred twelve (512) cells of the third grid. Therefore, the value of N for the third grid is five hundred nine (509). Using Fig.20 and Fig. 21, a more accurate value for the grid dimension (D_g) of the antenna may be calculated as follows:

$$D_g = -\frac{\log(509) - \log(128)}{\log(2 \times L2) - \log(L2)} \approx 1.9915$$

Multilevel Structures

In some examples, at least a portion of the conducting trace, conducting wire or conducting sheet of at least one antenna of the antennas included in the handset or handheld device may be coupled, either through direct contact or electromagnetic coupling, to a conducting surface, such as a conducting polygonal or multilevel surface. A multilevel structure is formed by gathering several geometrical elements, such as polygons or polyhedrons of the same type (e.g., triangles, parallelepipeds, pentagons, hexagons, circles or ellipses – in this context, circles and ellipses are considered to be polygons with a large number of sides-, as well as tetrahedral, hexahedra, prisms, dodecahedra, etc.) and coupling electromagnetically at least some of such geometrical elements to one or more other elements, whether by proximity or by direct contact between elements. The majority of the elements forming part of a multilevel structure have more than 50% of their perimeter (for polygon and surface like elements) not in contact with any of the other elements of the structure. Thus, the elements of a multilevel structure may typically be identified and distinguished, presenting at least two levels of detail: that of the overall structure and that of the polygon or polyhedron elements that form it.

Additionally, several multilevel structures may be grouped and coupled electromagnetically to each other to form higher-level structures. In a single multilevel structure, all of the component elements are polygons with the same number of sides or are polyhedrons with the same number of faces. However, this characteristic is not present when several multilevel structures of different natures are grouped and electromagnetically coupled to form meta-structures of a higher level.

A multilevel antenna includes at least two levels of detail in the body of the antenna: that of the overall structure and that of the majority of the elements (polygons or polyhedrons) which make it up. This may be achieved by ensuring that the area of contact or intersection (if it exists) between the majority of the elements forming the antenna is only a fraction of the perimeter or surrounding area of said polygons or polyhedrons.

One property of multilevel antennae is that the radioelectric behavior of the antenna can be similar in more than one frequency band. Antenna input parameters (e.g., impedance and radiation pattern) remain similar for several frequency bands (i.e., the antenna has the same level of adaptation or standing wave relationship in each different band), and often the antenna presents almost identical radiation diagrams at different frequencies. The number of frequency bands is proportional to the number of scales or sizes of the polygonal elements or similar sets in which they are grouped contained in the geometry of the main radiating element.

In addition to their multiband behavior, multilevel structure antennae may have a smaller than usual size as compared to other antennae of a simpler structure (such as those consisting of a single polygon or polyhedron). Additionally, the edge-rich and discontinuity-rich structure of a multilevel antenna may enhance the radiation process, relatively increasing the radiation resistance of the antenna and reducing the quality factor Q (i.e., increasing its bandwidth).

A multilevel antenna structure may be used in many antenna configurations, such as dipoles, monopoles, patch or microstrip antennae, coplanar antennae, reflector antennae, wound antennae, antenna arrays, or other antenna configurations. In addition, multilevel antenna structures may be formed using many manufacturing techniques, such as printing on a dielectric substrate by photolithography (printed circuit technique); dieing on metal plate, repulsion on dielectric, or others.

Summary of the invention

The invention relates to a device and method as defined in the independent claims. Some embodiments of the invention are defined in respective dependent claims.

The present invention relates *inter* alia to a handset or handheld device (such as for instance a mobile phone, a smartphone, a PDA, a MP3 player, a headset, a USB dongle, a laptop, a PCMCIA or Cardbus 32 card), which comprises a first antenna for mobile communications (hereinafter also referred to as the mobile antenna), and a second antenna for at least a mobile communication service or a wireless connectivity service (hereinafter also referred to as the wireless connectivity antenna), wherein the said second antenna is a slot antenna. The slot antenna can require a very small area on the PCB.

Slot antennas have conventionally not been considered appropriate for wireless handheld devices. Normally, conventional monopole antennas, patch antennas, inverted-F antennas (IFAs) and planar inverted-F antennas (PIFAs) have been considered more appropriate, maybe due to issues such as radiation efficiency and/or tradition.

However, it has been found that the use of a slot antenna as the wireless connectivity antenna for a handset or handheld device according to the present invention can be advantageous because:

- it has a low profile and uses very little space of the PCB;
- it is less sensitive to the size, shape or form factor of the PCB on which it is printed, etched, or mounted as an SMT component (see below). This can be particularly interesting for flip-type and slider-type handsets in which the antenna needs to stay within functional specifications for the PCB configuration of the handset in both the open and closed positions; and/or
- it can be polarized along a direction that is substantially orthogonal to the polarization of the mobile antenna.

Actually, using a second antenna in the form of a slot antenna can be preferred *inter alia* in order to increase the isolation between the antennas. One reason for this is that in order to increase isolation, it can be advantageous to establish the at least two antennas so that the polarization of the radiation of one of the antennas is substantially orthogonal to the polarization of the radiation of another of said antennas.

At a fist look, it could seem that this could also be easily accomplished by using, for example, two monopole antennas, directed in appropriate directions so as to establish an orthogonal relationship between the polarization of their radiations. However, a problem involved with hand-held devices is that the radiation of an antenna is substantially conditioned by the ground-plane, that is, normally, by at least one conductive layer of the PCB. In practice, normally both antennas are placed on the same ground-plane, therefore obtaining substantially orthogonally polarized radiation using two antennas of the same type can be a difficult task, due to the influence of the common groundplane. Contrarily, when one of the antennas is a slot antenna, the radiation from said

antenna will depend substantially less on the ground-plane, thus facilitating obtaining the above-mentioned orthogonally polarized radiation.

In the present document, the expression "mobile antenna" and similar are used to refer to an antenna arranged to operate in a band corresponding to a mobile communication service, such as one of the mobile communication services mentioned above (GSM -GSM850, GSM900, GSM1800, American GSM or PCS1900, GSM450-, UMTS, WCDMA, and CDMA). In some embodiments of the invention, the expression "mobile antenna" refers to an antenna arranged for or capable of fully functioning or operating in one, two, three or more communication standards, and in particular mobile or cellular communication standards, each standard allocated in one or more frequency bands. In some embodiments of the invention, each of said frequency bands is fully contained within one of the following regions of the electromagnetic spectrum:

- the 810MHz – 960MHz region,
- the 1710MHz – 1990MHz region,
- and the 1900MHz – 2170MHz region.

The expression "wireless connectivity antenna" as used in this document is defined further above. In some embodiments of the invention, the expression "wireless connectivity antenna" refers to an antenna arranged for or capable of fully functioning or operating in one, two, three or more communication standards, and in particular wireless connectivity standards, each standard allocated in one or more frequency bands. In some embodiments of the invention, each of said frequency bands is contained within one of the following regions of the electromagnetic spectrum, indicated as examples and without limitation:

- Industrial, Scientific, Medical (ISM) unlicensed bands, like for example the 915MHz ISM band (902–928 MHz), 2.4GHz ISM band (2400–2500 MHz), or 5.7GHz ISM band (5650–5925 MHz).

- Unlicensed general telemetry bands, like for example the 433.05–434.79MHz band, or the 868–870MHz band.

According to the present invention, good isolation between antennas can be obtained by appropriately choosing the orientation on the PCB, and by selecting the antenna type (i.e., whether a given antenna substantially behaves as an electric current source, or as a magnetic current source) for each one of the antennas comprised in the handset or handheld device. In the present invention, slot antennas can be considered to substantially behave as magnetic current sources; when fed across the slot, an electric field is established over the slot (and electric currents are flowing along the edges of the slot), and an equivalent magnetic field is established substantially parallel with the extension or orientation of the slot or slots.

In some cases, wherein the first antenna substantially behaves as an electric current source (such as for instance, but not limited to, a monopole antenna) and the second antenna substantially behaves as a magnetic current source (for instance, but not limited to, a slot antenna), good isolation between said first antenna and said second antenna can be obtained when the electric currents excited on at least a portion of the PCB (in this context, when referring to the PCB, reference is actually made to a conductive layer of the PCB, normally constituting a ground-plane of the handheld device) by the radiating mode of said first antenna are substantially parallel to the equivalent magnetic currents excited on at least a portion of the extension of said second antenna.

In other cases, wherein the first and second antenna both behave as magnetic current sources, good isolation between said first antenna and second antenna is achieved when the magnetic currents excited on at least a portion of the extension of the first antenna are substantially orthogonal to the

magnetic currents excited on at least a portion of the extension of the second antenna.

In order to improve isolation, the antennas can be placed separated as much as possible within the handset. In order to improve isolation, the antennas can be oriented with respect to each other so as to minimize coupling between the antennas. For example, the slot antenna can be placed on the PCB so that it is arranged substantially parallel to the currents induced in the PCB (in the ground-plane or conductive layer of the PCB) by the first antenna. This can imply, for example, arranging the slot (or slots) of the second antenna to be substantially or generally parallel to one of the sides of the ground-plane, for example, the longer sides of a substantially rectangular ground-plane.

In this document, an antenna or the slot of a slot antenna is considered to extend (to be oriented) in the direction corresponding to the general longitudinal axis of symmetry of the smallest rectangle in which the radiating element of the antenna can be inscribed. Also, in this document, two directions are considered to be substantially parallel if they form an angle of less than or equal to approximately 30 degrees. Two directions are considered to be substantially orthogonal if they form an angle of not less than approximately 60 degrees and not more than approximately 120 degrees.

It can be advantageous to have the slot arranged so that at least two, three, four or more portions of the slot are parallel to each other. This may apply to straight and to non-straight segments. With this parallel arrangement, very compact antennas can be achieved, occupying less space.

The slot antenna can be implemented as a slot printed on or etched in the ground plane of the PCB, while in other cases the slot will be contained in a

surface mount technology (SMT) type component mounted on the PCB of the handset or handheld device. When the slot is contained in a SMT type component, said component will comprise a conducting surface on which the slot is created. The SMT type component will provide at least one contact terminal accessible from the exterior of said SMT component to electrically connect said conducting surface with the ground plane of the PCB. In some embodiments, this contact terminal can take the form of a pad, or a pin, or a solder ball. It will be advantageous in some cases to define, on the PCB, a region of clearance of ground plane on the orthogonal projection of the component on the PCB on which it is mounted. In other cases, there will be ground plane on a portion of the orthogonal projection of the SMT component on the PCB, but not under the orthogonal projection of the slot on said PCB.

Yet in other embodiments, there will be ground plane also in a portion of the orthogonal projection of said slot on the PCB. In some examples, the fraction of the projection of the slot occupied by ground plane will be less than, or approximately equal to, 50%, 40%, 30%, 25%, 20%, 10% or 5% of the projection of the slot on the PCB.

A slot antenna integrated in an SMT component can be useful for minimizing the ground plane clearance region needed on the PCB. Embedding a slot antenna in a discrete SMT component can be difficult due to the necessity to ensure good grounding of the conducting sheet in which the slot has been created, and to the complexity to couple the feeding signal into the SMT component.

Some SMT component comprising slot antennas that can be used for the present invention are disclosed in PCT/EP06/062285, the content of which is incorporated herein, by reference.

Accordingly, SMT-type slot-antenna component useful in the present invention can comprise:

- at least one conductive surface (different from the conductive surface of the ground plane of the PCB) or a sheet of metal in which the pattern of a slot is created; and
- at least one contact terminal (also referred to as grounding terminal) accessible from the exterior of said component to electrically connect the conductive surface included in the slot-antenna component with the ground plane of the PCB.

With this component it is possible to provide a slot antenna as a separate component which can be connected from the outside. The antenna may further comprise:

- at least one contact terminal (hereinafter referred to as feeding terminal) to couple an electrical signal from the outside of the SMT-type slot-antenna component with the slot defined in said at least one conductive surface.

It will in principle also be possible to couple a feeding signal into the component indirectly by a capacitive or inductive coupling. For a good feeding, however, a direct electrical connection can be preferred. This can be achieved by the feeding terminal. In any case, the component does not need to have any internal means for generating an RF signal with which the antenna may be fed.

Further, it can be preferred that the component further comprises a

- dielectric substrate that backs said at least one conductive surface or sheet of metal, or in which said at least one conducting surface or sheet of metal is embedded.

The dielectric substrate allows for the backing of thin metal layers and is a widely used technique for the preparation of components for the electronics industry.

The terms sheet of metal and conductive surface are used as synonyms in the present document and relate to a conductive layer that can be supported by a circuit board or a piece of metal (for example, a rigid piece) such as e.g. a stamped metal piece.

Additional pads may be provided which are not electrically connected inside the component or to the ground plane or a feeding element of the circuit board. Those pads may be useful fore mechanically holding the antenna component by the solder connection at that pad between the component and the circuit board.

In some embodiments according to the present invention, the SMT component can also include one or several electronic elements or circuits, or the SMT component can take the form of an IC package. When the slot-antenna component takes the form of an IC package, then the slot contained in said IC package can preferably be excited with an RF feeding signal coupled from outside of said IC package, and not directly from a semiconductor die comprised inside said IC package.

In certain of these embodiments, the electronic elements or circuits included in the SMT component or IC package will preferably be placed within the SMT component or IC package in such a way that they do not interfere with the projection of the slot contained in the SMT component.

In some other embodiments, a slot-antenna component may comprise more than one, two or three conductive surfaces in which a slot or a portion of a slot

is created. By this technique it will be possible to "fold" the slot in the vertical direction, away from the PCB. Therefore, the footprint area on the PCB required for such an antenna can be significantly reduced in comparison to antennas where the slot is "folded" in a plane parallel to the PCB surface plane. Most conveniently, two conducting surfaces can be provided on the two opposite large sides of a circuit substrate. If a multilayer circuit substrate is used, further surfaces can be provided in order to form the slot antenna in the component.

The different surfaces may be connected or may remain unconnected. The connection may be done by a via hole or by a connection around the edge of a circuit substrate.

In order to protect a conducting layer, it will be advantageous to cover that layer with a protective layer, to prevent corrosion. Further, such a protective layer can be used to define terminals on the conducting layer which are then available for, e.g., a solder connection.

The antenna characteristics can further be chosen by using open-ended or closed-ended slot geometries. Any end of the antenna may be open or closed.

In some embodiments it is advantageous to place grounding terminals to connect the conductive surface with the ground-plane of the PCB close to at least two opposite edges of the slot-antenna component, preferably those two opposite edges that are the farthest apart from each other, so that the electric currents induced by the operation of the slot antenna on the conductive surface can flow through grounding terminals into the ground-plane of the PCB as if the conductive surface and the ground-plane of the PCB were one single conductive surface.

In certain cases it might be interesting to place a grounding terminal substantially close to at least two corners of said at least two opposite edges of the component, preferably the four corners of said two opposite edges of said component.

Further it can be preferred to extend one or more ground terminals along a major part of the length of an edge of the component or of the conductive surface. For example, the ground terminal may extend along at least 40%, 50%, 60%, 70%, 80%, 90% or 95% of the length of an edge. Thereby a good connection of the conductive surface to the ground plane of the PCB can be achieved. This is in particular the case where two grounding terminals extend along opposite edges such as the short and/or the long edges. One ground terminal may also be bent such that it is L- ,U- or O-shaped and is preferably provided along one, two, three or four neighboring edges.

Furthermore, in some embodiments it can be advantageous to place grounding terminals at two sides of a feeding terminal and substantially close to said feeding terminal. This arrangement can be used to effectively excite the slot.

Further in some cases it can be advantageous to provide the feeding terminals on two sides of the slot. Then it is possible to combine the slot with another slot by connecting the respective two edges of the two slots, thereby forming a larger slot.

In some embodiments the feeding means of the slot-antenna component comprise a feeding contact and a conductive strip. Said conductive strip can be advantageously printed or etched on the same conductive surface as the slot, thus making the feeding means coplanar with the slot. The conductive strip connects the feeding terminal with the edge of slot that is farther away from the contact terminal.

A clearance region can be provided at least on one, two, or three sides of the feeding terminal. This is in particular useful if the terminal is only used for feeding purposes. If the feeding terminal is also used for grounding purposes such clearance might not be present.

Also for the conductive strip a clearance may be provided. This clearance may not be necessary if the conductive strip is provided on a different level than the conductive surface with the slot. If the conductive strip is provided on a different level it may be connected to the conductive surface of the slot by a via hole or capacitive or inductive coupling. In the same way, the coupling between the feeding terminal and the conductive strip may be made by capacitive, inductive or direct electrical contact coupling.

In order to form pads on the PCB for receiving the terminals of the antenna component without however unnecessarily reducing the ground plane clearance, it is advantageous to provided protrusions of the ground plane which extend into clearance.

Further, the size of the area of the clearance may be smaller than the size of the antenna component.

In certain embodiments, the slot-antenna component is electrically coupled, by means of feeding terminals, with a slot created on the ground-plane of the PCB of the wireless device. In other words, a slot antenna is formed by combining the slot pattern printed or etched in the ground plane of the PCB, with the slot pattern included in the SMT component. Having a portion of the slot antenna printed or etched in the ground plane of the PCB can be advantageous, particularly because this:

- allows the fine tuning of the antenna to account for changes in the dimensions and/or form factor of the ground plane of the PCB to

which the slot-antenna component is connected, or the effects of dielectric (e.g., plastic) casings or enclosures, by simply acting on the portion of the slot antenna printed on the ground plane of the PCB.

- provides the PCB designer with more flexibility when laying out the different electronic components on the PCB, as the shape of the portion of slot antenna created in the ground plane can be selected, for example, to meet space constraints, or to minimize the distance of the antenna to the RF circuit.

Since this is achieved by acting only on the portion of the slot printed or etched on the ground plane of a PCB, while leaving the geometry of the slot contained in a conductive surface of an SMT component unchanged, such embodiments are effective in providing a standard component that can be used in a great variety of application environments.

In order to arrange the antenna such that as much space as possible is left over for other components, it can be advantageous to orient an edge, especially a long edge, of the SMT-type slot antenna component substantially parallel to the short or long edge of the circuit board.

The antenna component should not be to far away from the edge of the PCB. This facilitates providing a clearance and assures good radiation characteristics.

In some embodiments, the antenna component is preferably located on or close to the middle of an edge and in particular on or close to the middle of a long edge of the circuit board or the ground plane. A symmetric location with respect to the ground plane can provide a more predictable polarization characteristic since currents induced in the ground plane are not redirected in an asymmetric way by the shape of the ground plane. This may apply even if

the antenna itself is not symmetric but the location of the antenna on the ground plane is symmetric or almost symmetric.

The slot of the component may be excited by balanced or unbalanced feeding. This can be done with the help of a coplanar or coaxial transmission line or a microstrip transmission line.

By combining the slot of a ground plane and the slot of a slot-antenna component it is possible to obtain combined slots which are open at none, one, or two ends.

If such a combined slot is provided, this combined slot may be excited by exciting the slot portion of the antenna component or the slot portion of the ground plane. The latter may be preferred since with this technique it is possible to connect an RF-generator directly with the ground plane of the circuit board on which the RF-generator itself is arranged.

Another aspect of the invention relates to a technique to further improve the isolation between a mobile antenna and a wireless connectivity antenna in a handset or handheld device, for example, by acting on the geometry of the mobile antenna to eliminate any resonance modes that might fall within any of the operating bands of the wireless connectivity antenna, in line with what is claimed and described below. In the present text, "operating band" especially implies a band in which the antenna features similar values for a number of parameters representative of the antenna performance.

List of figures

Further characteristics and advantages of the invention will become apparent in view of the detailed description which follows of some preferred embodiments of the invention given for purposes of illustration only and in no way meant as a

definition of the limits of the invention, made with reference to the accompanying drawings, in which:

Fig. 1 – Example of a prior art slider-type handset carrying an antenna for mobile communications (101) and comprising a top PCB (100) (the dimensions of which could be, for example, 78mm x 40mm) and a bottom PCB (102) (for example, with the dimensions 70mm x 35mm): **(a)** General view of the PCBs of the handset in the closed position; and **(b)** general view of the PCBs of the handset in the open position.

Fig. 2 – Top view of an example of a prior art handset comprising a first antenna for mobile communications placed on the top portion of the PCB of the handset and a second antenna for wireless connectivity services placed on the bottom right corner of the PCB.

Fig. 3 – Typical electrical performance of the antennas of the handset shown in Fig. 2: **(a)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and **(b)** return loss of each antenna and isolation between antennas when the handset is in open position.

Fig. 4 – Top view of a handset according to an embodiment of the present invention, including a first antenna for mobile communications placed on the top portion of the PCB of the handset and a second antenna for wireless connectivity services placed on the bottom right corner of the PCB, wherein the second antenna is a slot antenna: **(a)** General view of the PCB of the handset carrying the two antennas; and **(b)** detailed view of the region that contains the slot antenna.

Fig. 5 – Typical electrical performance of the antennas of the handset shown in Fig. 4: **(a)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and **(b)** return loss of each antenna and isolation between antennas when the handset is in open position.

Fig. 6 – Typical radiation and antenna efficiency of the slot antenna for wireless connectivity integrated in the handset of Fig. 4.

Fig. 7 – Top view of some implementations of the handset comprising a mobile antenna 701 and a slot antenna (black line) 702 on the PCB (700) for wireless connectivity services.

Fig. 8 – Typical electrical performance of the antennas of the handset shown in Fig. 7b: **(a)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and **(b)** return loss of each antenna and isolation between antennas when the handset is in open position.

Fig. 9 – **(a)** Detailed view of an example of a handset comprising a first antenna for mobile communications and a second antenna for wireless connectivity services. The geometry of the antenna for mobile communications can be tailored according to the teachings of the present invention to enhance the isolation with the antenna for wireless connectivity services by **(b)** modifying the dimensions of an arm of the mobile antenna; or **(c)** folding an arm of the mobile antenna.

Fig. 10 – Comparison of typical levels of isolation between the mobile antenna and the wireless connectivity antenna that can be obtained before and after modifying the mobile antenna as depicted in Fig. 9b.

Fig. 11 – Detailed view of an antenna for mobile communications whose geometry has been modified according to the teachings of the present invention to enhance the isolation with the antenna for wireless connectivity services by increasing the length of a slot defined in the structure of the mobile antenna by means of: **(a)** shaping the slot as a meander-like curve; or **(b)** adding a conductive strip inside the aperture of the slot.

Fig. 12 – Comparison of typical levels of isolation between the mobile antenna and the wireless connectivity antenna that can be obtained before and after modifying the mobile antenna as depicted in Fig. 11b.

Fig. 13 – Detailed view of the top portion of the PCB of a handset showing different embodiments according to the present invention to enhance the isolation between an antenna for mobile communications and an antenna for wireless connectivity services by: **(a)** introducing a slot on the PCB; or **(b)** placing a conductive stripe above the PCB that is shorted on one end to the PCB.

Fig. 14 – Comparison of typical levels of isolation between the mobile antenna and the wireless connectivity antenna that can be obtained before and after modifying the PCB of the handset as depicted in Fig. 13b.

Fig. 15 – Embodiment of a handset according to the present invention including a mobile antenna, a wireless connectivity antenna, and parasitic element to enhance the isolation between antennas: **(a)** General view of the PCB of the handset; and **(b)** detailed view of the top portion of the PCB of the handset showing the shape of the parasitic element. (For the sake of clarity, in Fig. 15b the parasitic element appears to be above the mobile antenna, although in reality it is placed below the mobile antenna but above the plane of the PCB of the handset, that is, between the mobile antenna and the PCB of the handset.)

Fig. 16 – Comparison of typical levels of isolation between the mobile antenna and the wireless connectivity antenna that can be obtained before and after introducing a parasitic element, like the one shown in Fig. 15, in the handset.

Fig. 17 – Example of a box counting curve located in a first grid of 5x5 boxes and in a second grid of 10x10 boxes.

Fig. 18 – Example of a grid dimension curve.

Fig. 19 – Example of a grid dimension curve located in a first grid.

Fig. 20 – Example of a grid dimension curve located in a second grid.

Fig. 21 – Example of a grid dimension curve located in a third grid.

Fig. 22 – Example of a slot antenna component.

Fig. 23 – Different examples of possible locations of a slot antenna component on the circuit board.

Description of the preferred embodiments

In some preferred embodiments of the handset or handheld device of the present invention, said handset or handheld device comprises a first antenna used for at least one mobile communication service, and a second antenna used for at least one wireless connectivity service, wherein the second antenna is a slot antenna (cf. for example Figure 4). In the example of Figure 4, and without being a limitation of the invention, the slot (402) has been created in the ground plane of the PCB (400) (namely, in a conductive metal layer of the PCB) on its right hand side and near the bottom (considering a groundplance arranged in the vertical plane and with the mobile antenna 401 at its top end, as illustrated in Figure 4). The shape of the slot (402), and the length and widths of each one of the segments that form the said slot (402), can be selected to meet the requirements of resonance frequency, electrical performance, and maximum PCB area constraint, of a given handset or handheld device.

In the example of Figure 4, the slot (402) intersects the perimeter of the ground plane of the PCB (400) at one point (406). In other words, the slot (402) is not completely surrounded by conducting materials. In some preferred cases, the unfolded length of the slot (402) will be approximately a quarter of an operating wavelength of the slot antenna. In some other cases, the unfolded length of the slot (402) will be approximately three times, or approximately five times, or approximately another odd integer number of times, the length of one quarter of an operating wavelength of the slot antenna.

In other embodiments, the slot might intersect the perimeter of the ground plane of the PCB on which is placed at least at one point, such as for example at two points. In yet some other embodiments, the slot might not intersect the perimeter of the ground plane of the PCB on which is placed. That is, the slot is in these cases completely surrounded by conducting material (in the layer or layers containing the slot). In some embodiments, it might be advantageous that the unfolded length of the slot be approximately twice, or approximately four times, or approximately another even integer number of times, the length of one quarter of an operating wavelength of the slot antenna.

In order to minimize the coupling between the first antenna (401) and the second antenna (402) (i.e., to maximize the isolation), the design of the slot (402) and its orientation with respect to the PCB (400) is selected such that the slot (402) is substantially parallel to the direction of the currents excited on the PCB (400) by a resonating mode of the first antenna (401), at least on a portion of the PCB (400). In some cases, it is advantageous to design the slot (402) such that it is substantially parallel to the longer side of the conductive layer or ground-plane of the PCB (400), because the currents excited on said PCB (400) by the resonating mode of the first antenna (401) tend to be substantially parallel to said longer side of the PCB (400). In the

context of this application, two directions are considered to be substantially parallel if they form an angle of less than, or equal to, approximately 30 degrees. Also in the context of this application, the direction of a slot is defined by the direction of the longest side of the minimum rectangular area in which said slot is or can be inscribed.

In some other cases, the first antenna may include a slot that radiates at a particular resonance frequency, so that said first antenna behaves substantially as a magnetic current source for that resonance frequency. In these embodiments it will be advantageous to align the said slot of the first antenna along a first direction and the slot of the second antenna along a second direction, said first direction being substantially orthogonal to said second direction. In the context of this application, two directions are considered to be substantially orthogonal if they form an angle in the range from approximately 60 degrees to approximately 120 degrees.

The shape of the slot (402) can comprise straight and curved segments, not necessarily all segments being of the same length (see examples in Figure 7). In the same way, the separation between the conductive edges of each segment of the slot (402) does not have to be the same for all segments, nor constant for any given segment (i.e., any segment of the slot (402) can be tapered).

In some examples, the slot (402) might have one, two, three, or more bends. In general, as the number of bends in the slot (402) increases, the shape of the slot (402) becomes more and more convoluted, leading to a higher degree of miniaturization of the resulting slot antenna.

In some cases, the slot antenna can advantageously be excited by applying a voltage difference between the opposite conductive edges of the slot (402) at a particular point (408) along the geometry of the slot (hereinafter referred

to as the feeding point). In some embodiments, the feeding point (408) will be closer to the closed end of the slot (407) than to the open end of the slot (406). In certain examples, the distance between the feeding point (408) and the closed end of the slot (407) will be less than, or equal to, 0.2%, 0.4%, 0.8%, 1.2% 1.6%, 2.5%, 3.3%, 4% or 8% of a free-space operating wavelength of the slot antenna.

In some examples, it will be advantageous to have the slot antenna (402) inscribed in a rectangular area (403) of width (405) smaller than 1/50 of the free-space operating wavelength of the slot antenna (402), and length (404) smaller than 1/4 of the free-space operating wavelength. Being more general, in some embodiments the said width (405) divided by the free-space operating wavelength of the slot antenna will be smaller than, or equal to, at least one of the following fractions: 1/10, 1/30, 1/50, 1/60, 1/70, or 1/80. In the same way, for some embodiments, said length (404) divided by the free-space operating wavelength of the slot antenna can be smaller than, or equal to, at least one of the following fractions: 1/2, 1/3, or 1/4. In some other instances, it will be advantageous that the sum of the length (404) and the width (405) of the rectangular area (403) in which the slot is inscribed be smaller than 1/2 of the free-space operating wavelength, or even smaller than 1/4 of the free-space operating wavelength. Furthermore, it will be advantageous in some cases that the separation between the two edges of the slot (402) be within a range from approximately 0.08% of the free-space operating wavelength to approximately 8% of a longest free-space operating wavelength, including any subinterval of said range.

Figure 5 presents, without any limiting purpose, an example of electrical results for the handset of Figure 4 according to the present invention. Figure 5a presents typical values of the input parameters of the antennas (i.e., return losses of each antenna, and isolation between antennas) when the slider-type phone is in the closed position, while Figure 5b presents the typical results of

the antennas when the phone is in the open position. In this example, the first antenna (401) was designed to have a multiband behavior, with a first resonance around 900MHz to provide coverage for the GSM900 service, and a second resonance around 1900MHz to provide service under the GSM1800 and GSM1900 standards. On the other hand the second antenna was designed to be tuned in the 2500MHz band. The isolation between the first antenna (401) and the second antenna (402) exceeds 30dB in the 900MHz band, is better than 23dB in the 1900MHz band, and better than 21dB in the 2500MHz band. The level of isolation attained between the antennas of the example shown in Figure 4 is better than the results obtained for the example of a conventional prior-art arrangement in Figure 2. A typical radiation performance of the slot antenna (402) is shown without any limiting purpose in Figure 6. The slot antenna (402) has a level of radiation efficiency in excess of 60% in its band of operation both in the open and closed positions of the handset.

Figure 7 presents, without any limiting purpose, some embodiments for the present invention of a handset or handheld device comprising a slot antenna. Generally, it will be preferable to keep the separation between the mobile antenna (701) and the wireless connectivity antenna (702) as large as possible in order to maximize the isolation between the antennas. For example, isolation between the antennas on the PCB for the case of Figure 7c is expected to be better than for the case of Figure 7a, as the separation between the antennas is larger. However, in certain embodiments it may not be possible to place the mobile antenna (701) and the wireless connectivity antenna (702) further apart. In these cases it will be especially necessary or convenient to use additional techniques to further improve the isolation between the mobile antenna and the wireless connectivity antenna by acting either on the geometry of the mobile antenna, or on the PCB of the handset or the handheld device, or on both.

The electrical performance of the antennas in the embodiment of Figure 7b is presented without any limiting purpose in Figure 8. As it can be observed, the return loss of each antenna is practically the same as the one already presented in Figure 5. However, there is a degradation in the isolation between the mobile antenna (701) and the wireless connectivity antenna (702), predominantly around 2400MHz, linked to the smaller separation between the antennas.

Another aspect of the invention relates to techniques to enhance the isolation between the mobile antenna and the wireless connectivity antenna. Some of these techniques comprise the steps of shaping the geometry of the mobile antenna to eliminate higher order resonant modes or spurious modes that may fall within an operating band of the wireless connectivity antenna (or vice-versa), giving rise to strong coupling of the mobile antenna with the wireless connectivity antenna.

In some embodiments, the mobile antenna can comprise features (such as, for instance, a slot, or a strip of metal) with an electrical length close to approximately an integer multiple of a quarter of an operating wavelength of the wireless connectivity antenna. For example, in the embodiment of Figure 9a, the mobile antenna (901) comprises a slot (903) that has a length of approximately a quarter of the wavelength at 2600MHz, corresponding to an operating band of the wireless connectivity antenna. For the purposes of this example and the following ones, a wireless connectivity antenna (902) (for example, embodied in a slot antenna component) has been placed near the top left corner of the PCB (900) underneath the mobile antenna (901). As commented previously, this is not a particularly advantageous position for the wireless connectivity antenna (902), as the little distance with respect to the mobile antenna (901) can imply poor isolation. As it can be seen in Figure 10, a typical level of isolation between antennas at 2600MHz is approximately 8dB. However, this antenna arrangement will help to illustrate the improvement in

isolation between antennas that can be achieved by following the teachings disclosed in this patent application.

In order to increase the isolation between antennas, the length of the slot (903) can be shortened to force the associated resonance frequency to move towards higher frequencies, away from the wireless connectivity band. In the embodiment illustrated in Figure 9b, the conducting arm of the mobile antenna (934) has been shortened by some amount with respect to the original arm (904), so that the resulting slot (933) is shorter or substantially shorter than a quarter of the relevant resonant wavelength of the wireless connectivity antenna and therefore resonates at a higher frequency.

The resonance frequencies of the mobile antenna (931) might shift in frequency as a consequence of the shortening of the conducting arm (934). The operating bands of the mobile antenna (931) can be readily retuned using for example a matching network at the feeding point of the antenna. As an alternative, it can be preferred to lengthen the arm (934) to retune the operating bands of the mobile antenna (931), while keeping the length of slot (933) constant. In that sense, the embodiment in Figure 9c shows a mobile antenna (961) in which the conducting arm (964) has been folded as a U shape, while ensuring that the length of the slot (963) is shorter than that of the slot (903) in figure 9a. In this case, the end of the conducting arm (964) does not coincide with the open end of the slot (963), as it was the case of embodiment in Fig. 9a, where the tip of arm (904) defined the open end of the slot (903). Figure 10 presents without any limiting purpose a typical antenna isolation that can be obtained with a modified mobile antenna like the one in Figure 9c, and compares it with the isolation obtained with the original mobile antenna (Figure 9a).

In some cases, in order to achieve a good improvement in isolation between antennas, the length of a slot, or a conducting strip, or more generally a geometric feature of the mobile antenna which has an associated resonance

within a band of the wireless connectivity antenna, will be modified (i.e., shortened or enlarged) about 12%, or about 20%, or even about a 30%, of the original length of said slot, or said conducting strip, or said geometrical feature of the mobile antenna.

In some other embodiments it can be advantageous to increase a dimension of a feature of the mobile antenna with an associated resonance at a frequency within an operating band of the wireless connectivity antenna. Figure 11 discloses two embodiments of a handset comprising a mobile antenna and a wireless connectivity antenna that use this technique to improve the antenna isolation. In the case of Figure 11a, the slot (903) in the original mobile antenna (901) has been replaced by a meander-like slot (1103) to make it electrically longer and shift the resonance associated to this slot (1103) well below the operating band of the wireless antenna (1102). In some embodiments of the present invention at least a portion of the slot (1103) will be preferably shaped as a space-filling curve, a box-counting curve, a grid-dimension curve, or a fractal based curve, to achieve maximum size compression.

The embodiment in Figure 11b illustrates another way of increasing the electrical length of the slot (903) of the original mobile antenna (901). In this case, the mobile antenna (1151) comprises a metal strip (1154) that is placed between the edges of the slot (903) and shorted at one end to the main body of the mobile antenna (1151) in the region (1155). In certain cases, the metal strip (1154) will be long enough to cover substantially the slot (903), while in other cases the metal strip (1154) will be shorter and be placed in just a portion of the slot (903). The resulting "U-shaped" slot will have an associated resonance frequency lower than that of the original slot (903). Figure 12 presents without any limiting purpose a typical antenna isolation that can be obtained with a modified mobile antenna like the one in Figure 11b, and compares it with the isolation obtained with the original mobile antenna (Figure 9a). In some embodiments, such a technique improves the isolation by 4dB or more.

Some other techniques to enhance the isolation between the mobile antenna and the wireless connectivity antenna in a handset or handheld device according to the present invention comprise the steps of modifying the geometry of the PCB of said handset or handheld device to introduce on said PCB a feature able to increase the isolation between antennas in a particular frequency band.

Figure 13a presents an embodiment of a handset comprising a mobile antenna (1301), a wireless connectivity antenna (1302) and a PCB (1300), wherein a slot (1304) has been created in a ground plane of said PCB (1300). The slot (1304) features an open end. That is, the slot (1304) intersects the perimeter of the conducting pattern of the PCB (1300) in at least one point. In other words the slot (1304) is not completely surrounded by conducting materials. In this example, the unfolded length of the slot (1304) has been selected to be approximately a quarter of the wavelength at the frequency for which the isolation between antennas needs to be enhanced. More generally, the length of the slot (1304) can be adjusted to be approximately an odd integer multiple of a quarter of the wavelength at the frequency for which a higher level of isolation is needed.

A purpose of the slot (1304) is to present a high impedance path to the currents flowing on the perimeter of the ground plane of the PCB (1300) on which the slot (1304) is placed and/or along a preferred path between the feeding points of the first and second antennas (the feeding point of said second antenna (1302) is placed under the first antenna (1301), at the left of the slot (1304) in figure 13a). Therefore, it will be preferred in certain embodiments, in order to increase the isolation, to place the slot (1304) at a point along the perimeter of the ground plane of the PCB (1300) in which the currents flowing from the wireless connectivity antenna (1302) towards the mobile antenna (1301) along the perimeter of the ground plane of the PCB (1300) are strong. In other

embodiments, a purpose of shaping the ground plane with for instance one or more slots is to alter the phase and amplitude of the coupling and to generate multiple signal coupling paths such that those multiple signals cancel or partially cancel each other.

Figure 13b discloses another embodiment of a handset comprising a mobile antenna (1301), a wireless connectivity antenna (1302) and a PCB (1350), wherein a conductive stripe (1354) has been placed above, and substantially parallel to, the ground plane of the said PCB (1350) and shorted at one end to the said PCB (1350). In the example of the figure, the unfolded length of the conducting stripe (1354) has been selected to be approximately a quarter of the wavelength at the frequency for which the isolation between antennas needs to be enhanced. Being more general, the length of the conducting stripe (1354) can be adjusted to be approximately an odd integer multiple of a quarter of the wavelength at the frequency for which a higher level of isolation is needed.

Similarly to the slot (1304) in Figure 13a, a purpose of the conducting strip (1354) is to present a high impedance path to the currents flowing on the ground plane of the PCB (1350) from the wireless connectivity antenna (1302) towards the mobile antenna (1301) (or viceversa). Therefore, it will be advantageous in some cases, to place the shorted end of the conducting stripe (1354) at least a distance of approximately a quarter of the wavelength at the frequency for which a higher level of isolation is needed, on the path that the currents flowing from the wireless connectivity antenna (1302) towards the mobile antenna (1301) follow on the ground plane of the PCB (1350) (or viceversa).

Figure 14 presents, without any limiting purpose, typical antenna isolation that can be obtained by using a handset with a modified PCB as the one disclosed in Figure 13b. Compared with the isolation curve obtained in the original handset (Figure 9a), the presence of the shorted conducting strip (1354)

introduces a deep notch in the isolation in the region between 2600MHz and 2800MHz, where the original handset had a poor isolation.

In other embodiments, the ground plane of the PCB of the handset or handheld device can have two or more slots, like the slot (1304) in Figure 13a, or two or more conducting strips shorted to the ground plane of the PCB, like the conducting stripe (1354) in Figure 13b. By adjusting the number and length of the slots or the conducting strips, the frequency behavior of the isolation between antennas can be tailored. In general, for a wide-band behavior, the length of the slots or the conducting strips will be substantially similar. For a multiband response with no overlapping between frequency bands, the length of each slot or each conducting strip is associated mainly with the center frequency of a particular band at which the isolation between antennas needs to be increased. In yet other embodiments, a single slot (or a single conducting strip) with multiple branches can be used to obtain an improvement in the isolation with a wideband or multiband behavior.

In yet other embodiments, the handset or handheld device comprises a mobile antenna (1501), a wireless connectivity antenna (1502), and a conducting strip (1504) placed in the vicinity of the mobile antenna (1501) and the wireless connectivity antenna (1502), but differently from what is disclosed in Figure 13b, said conducting strip (also referred to as parasitic element) is not connected to the ground plane of the PCB (1500). In the example of the Figure 15, the unfolded length of the conducting strip (1504) has been selected to be approximately half of the wavelength at the frequency for which the isolation between antennas needs to be enhanced. The resonance introduced by said conducting strip (1504) enhances the curve of isolation between antennas (see Figure 16, which is provided for the purposes of illustration only and in no way meant as a definition of the limits of the invention), improving substantially the isolation in the desired band (the 2600MHz – 2800MHz region in this particular

example). This conductive strip (1504) basically functions as a shield for the electromagnetic radiation between the two antennas.

In some embodiments of the present invention (see for example Figures 13 and 15) at least a portion of the slot (1304), or a portion of the conducting strip (1354, 1504) will preferably be shaped as a space-filling curve, a box-counting curve, a grid-dimension curve, or a fractal based curve, to achieve maximum size compression.

A person skilled in the art will recognize that the techniques disclosed in this patent application can be advantageously used to enhance the isolation between an antenna for mobile communications and an antenna for wireless connectivity services not only when the latter is a slot antenna but also for other types of antenna topology such as for instance, but not limited to, a monopole antenna, an IFA, a patch antenna or a PIFA.

Fig. 22 shows an example of slot-antenna component 2210 according useful for present invention, including a conductive surface 2211, in which a slot 2213 has been created, a dielectric substrate2212, five grounding terminals 2215 and feeding means comprising a feeding terminal 2214. In Fig. 22a a perspective bottom view of the slot-antenna component (i.e., as seen from the side of the component facing the PCB on which it is to be mounted) is shown. Fig. 22b is a top view of the component (i.e., as seen from the side of the component not facing the PCB on which it is to be mounted).

The conductive surface 2211 is backed by a dielectric substrate 2212. In this particular embodiment, and without limiting purposes, the contour of the slot 2213 is inspired in the Hilbert curve; however, other shapes could also be used. In fact, the shape of the slot 2213, and the length and width of each one of the segments that form said slot 2213, can be selected to meet the

requirements of resonance frequency, electrical performance, and maximum size, of a given SMT component.

In a preferred embodiment, the conductive surface 2211 is covered by another dielectric layer (such as for example a layer of ink, or a layer of protective epoxy coating for environmental protection), in which some windows are left in order to create one or more contact terminals 2214, 2215 of the component 2210. In Fig. 22, the slot-antenna component 2210 comprises one feeding terminal 2214 and several grounding terminals 2215. The contact terminals 2214, 2215 have been depicted as square pads, although they could be shaped differently, or take the form of pins or BGA balls.

All contact terminals 2214, 2215 are arranged on or close to the edge of the conductive surface 2211 and at the same time on or close to the edge of antenna component 2210.

In figure 22, the feeding means of the slot-antenna component 2210 comprise a feeding contact 2214 and a conductive strip 2218 that can be advantageously printed or etched on the same conductive surface 2211 as the slot 2213, thus making the feeding means coplanar with the slot 2213. The conductive strip 2218 connects the feeding terminal 2214 with the edge of the slot 2213 that is farther from the contact terminal 2214 in region 2219 along the slot 2213. In the example of Fig. 12, the connection of the conductive strip 2218 with the edge of the slot 2213 that is farther from the contact terminal 2214 occurs at a substantially right angle (i.e., an angle of approximately 90°), however said connection could also occur at angles smaller or larger than 90°.

In said region 2219, the edge of the slot 2213 that is closer to the feeding terminal 2214 is interrupted, so that the conductive strip 2218 can cross the slot 2213 reaching the farther edge of said slot 2213. A clearance region 2220 is created at both sides of the conductive strip 2218 and the feeding terminal

2214. The width of the clearance region 2220 does not need to be necessarily the same on both sides of the conductive strip 218 and the feeding terminal 2214. The input impedance of the slot antenna can be appropriately selected by means of the distance of the region 2219 to an end of slot 2217, the width of the conductive strip 2218 and the widths of the clearance region 2220 on each side of the conductive strip 2218, and the feeding terminal 2214.

In certain embodiments, said widths can be substantially equal. In some cases, the width of the conductive strip 2218 and the widths of the clearance regions on each side thereof can be advantageously selected so as to form a coplanar transmission line. The width of the conductive strip 2218 and the widths of said clearance regions will preferably be smaller than a maximum width. Some possible values for said maximum width comprise 1/2400, 1/1200, 1/800, 1/600, 1/480, 1/400, 1/300, 1/240, 1/200, 1/150 and 1/120 of a free-space operating wavelength of the slot antenna.

In some cases, it will be advantageous to place a grounding terminal 2215 at each side of the feeding terminal 2214. In other examples, the feeding terminal 2214 might not be coplanar with the slot 2213, making it necessary to couple a feeding signal from the feeding terminal 2214 to the conductive strip 2218 either by direct contact (such as for instance by means of a via hole), or by electromagnetic coupling (either capacitive or inductive). Capacitive (or inductive) coupling can be preferred in some cases to compensate for an inductive (or capacitive) component of the input impedance of the slot antenna, without having to use external circuit elements such as capacitors or inductors.

Figure 22 shows an example of the slot-antenna component 2210 in which the slot antenna is excited in an unbalanced manner. In some other examples, a slot-antenna component could be excited in a balanced manner by including a first feeding terminal to provide a positive potential (referenced to a ground potential) and a second feeding terminal to provide a negative potential

(referenced to said ground potential). In some cases, the component can also include a third feeding terminal to provide said ground potential.

In the embodiment of Fig. 22, the slot 2213 has a first end 2216 that intersects the perimeter of the conductive surface 2211. That is, the slot 2213 is open-ended at said first end 2216. Furthermore, the second end 2217 of the slot does not intersect the perimeter of the conductive surface 2211 (i.e., it is closed-ended).

In Fig. 23 examples of how a slot-antenna component 2210 can be placed on a substantially rectangular PCB 2300 of a wireless (e.g. handheld or portable) device are shown. In Fig 23a the longer dimension of the slot-antenna component 2210 is aligned with one of the longer edges of the PCB 2300, and substantially centered along said edge. Fig. 23b relates to the case where the longer dimension of the slot-antenna component 2210 is aligned with one of the longer edges of the PCB 2300, and substantially close to a corner of said edge and in Fig. 23c the longer dimension of the slot-antenna component 2210 is aligned with one of the shorter edges of the PCB 2300, and substantially close to a corner of said edge. It may also be centered along the short edge.

In Fig. 23, the conductive layer of the PCB 2300 has been removed or, at least, partly removed under the slot-antenna component 2210, that is, in correspondence with the footprint of the slot-antenna component on the PCB, that is, in correspondence with its projection on the PCB 2300.

Generally, the present invention can facilitate the integration of the antennas inside several kinds of handsets or handheld devices so that the antennas can be arranged in a way that it is compatible with high density of components on the PCB of the device. For miniaturization purposes, at least a portion of the curve defining the conducting trace, conducting wire or contour of the conducting sheet of at least one antenna of the handset or handheld device will

advantageously be a space-filling curve, a box-counting curve, a grid-dimension curve, or a fractal based curve. The conducting trace, conducting wire or contour of the conducting sheet of said at least one antenna might take the form of a single curve, or might branch-out in two or more curves, which at the same time in some embodiments will be also of the space-filling, box-counting, grid-dimension, or fractal kinds. Additionally, in some embodiments a part of the curve will be coupled either through direct contact or electromagnetic coupling to a conducting polygonal or multilevel surface.

The teachings disclosed in the present patent application facilitate the adoption of the wireless functionality in handsets and other handheld devices. Handset and handheld device manufactures will benefit from the commercialization of such products with value-added features and that enjoy of stronger customer preference. In a platform like the one of a handset for mobile communications in which the efficient use of small-sized PCBs is paramount, the integration of a wireless connectivity antenna according to the present invention offers the benefit of small area overheads (i.e., smaller overall size of the handheld device), which translates into lower cost. Moreover, the enhanced isolation between antennas attainable using the techniques and teachings of the present invention provide handset and handheld device manufacturers with more flexibility when designing the layout of the PCB of the devices and the placement of the antennas and neighboring electronics on the PCB of the devices, reducing the costs of integration of the antenna, simplifying the new product development cycle, and accelerating the time to market of their new products.

In some preferred embodiments the handset or handheld device is operating at one, two, three or more of the following communication and connectivity services: GSM (GSM850, GSM900, GSM1800, American GSM or PCS1900, GSM450), UMTS, WCDMA, CDMA, Bluetooth™, IEEE802.11ba,

IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DMB, DVB-H.

WHAT IS CLAIMED IS:

1. A handheld device comprising:

at least one printed circuit board;

a first antenna capable of transmitting and receiving electromagnetic wave signals in at least three frequency bands;

a second antenna arranged to operate in a first frequency band;

wherein said first frequency band is different from any frequency band of said at least three frequency bands; and

wherein the second antenna is a slot antenna comprising at least one slot in at least one conductive layer.

2. The handheld device according to claim 1, wherein said at least one conductive layer is a conductive layer of said at least one printed circuit board, wherein said slot antenna comprises at least one slot in said conductive layer of said at least one printed circuit board.

3. The handheld device according to claim 1, wherein said at least one slot has a closed end and an open end, said open end being arranged in correspondence with a perimeter of said at least one conductive layer, wherein said at least one slot is not completely surrounded by conductive material in a plane or planes of said at least one conductive layer.

4. The handheld device according to claim 4, wherein said second antenna comprises at least one feed point, wherein said at least one feed point is situated closer to said closed end than to said open end.

5. The handheld device according to claim 1, wherein said at least one slot comprises two closed ends, wherein said at least one slot is completely surrounded by conductive material in a plane or planes of said at least one conductive layer.

6. The handheld device according to claim 1, wherein said second antenna comprises at least one feed point, wherein said at least one feed point is situated

at a distance from a closed end of said slot less than, or equal to, a value selected from the group comprising 0.2%, 0.4%, 0,8%, 1.2%, 1.6%, 2.5%, 3.3%, 4% and 8% of a free-space operating wavelength of the second antenna.

7. The handheld device according to claim 1, wherein said at least one slot antenna has a size so that the at least one slot antenna can be inscribed in a rectangle having a width of less than 1/50 of a free-space operating wavelength of the at least one slot antenna.

8. The handheld device according to claim 1, wherein said at least one slot antenna has a size so that the at least one slot antenna can be inscribed in a rectangle having a length of less than 1/4 of a free-space operating wavelength of the at least one slot antenna.

9. The handheld device according to claim 1, wherein said at least one slot has an unfolded length corresponding to approximately (2N-1)*A/4, where A is an operating wavelength of the second antenna and N is an integer, N>1.

10. The handheld device according to claim 1, wherein said at least one slot has an unfolded length corresponding to approximately (2N)*A/4, where A is an operating wavelength of the second antenna and N is an integer, N>1.

11. The handheld device according to claim 1, wherein said at least one printed circuit board comprises a ground-plane having a generally rectangular configuration comprising two shorter sides and two longer sides, wherein said at least one slot antenna comprises at least one slot extending in a direction substantially parallel to one of said two longer sides.

12. The handheld device according to claim 11, wherein said first antenna is arranged extending in a direction substantially parallel to one of said two shorter sides.

13. The handheld device according to claim 11, wherein said second antenna is arranged substantially at a center portion of one of said two longer sides.

14. The handheld device according to claim 11, wherein said first antenna is arranged substantially adjacent to one of said two shorter sides.

15. The handheld device according to claim 11, wherein said second antenna has a longitudinal extension substantially parallel to one of said two longer sides.

16. The handheld device according to claim 1, wherein said handheld device further comprising at least one slot in a ground-plane of said at least one printed circuit board, wherein said at least one slot is arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said ground-plane between said feeding points at at least one frequency band corresponding to an operating band of one of said first and second antennas.

17. The handheld device according to claim 16, wherein said at least one slot in the ground-plane has an open end in correspondence with a perimeter of said ground-plane.

18. The handheld device according to claim 16, wherein said at least one slot in the ground-plane has a length of approximately (2N-1)*A/4, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, N>1.

19. A handheld device comprising:

a printed circuit board including a ground plane;

a first antenna operating in a plurality of frequency bands, said first antenna being capable of transmitting and receiving electromagnetic wave signals in each frequency band of said plurality of frequency bands;

a second antenna operating in at least a first frequency band, said second antenna being capable of transmitting and receiving electromagnetic wave signals in said first frequency band;

wherein said first frequency band is different from any frequency band of the plurality of frequency bands;

wherein the said first antenna is selected from the group consisting essentially of monopole antenna, IFA, patch antenna, and PIFA;

wherein the second antenna is a slot antenna comprising a slot having an open end, wherein the slot antenna is included in the ground plane of the printed circuit board, wherein a longest straight segment of the slot is substantially parallel to a longest edge of the printed circuit board, wherein the open end of the slot is in contact with an edge of the printed circuit board;

wherein a width of a rectangular area in which the slot antenna is inscribed, divided by a free-space operating wavelength of the slot antenna is smaller than, or equal to, at least one of the following fractions: 1/10, 1/30, 1/50, 1/60, 1/70, or 1/80;

wherein a length of the rectangular area in which the slot antenna is inscribed, divided by a free-space operating wavelength of the slot antenna is smaller than, or equal to, at least one of the following fractions: 1/2, 1/3, or 1/4;

wherein the handheld device is a mobile handset, operating in at least one of the following mobile communication and wireless connectivity services:

GSM (GSM850, GSM900, GSM1800, American GSM or PCS1900, GSM450), UMTS, WCDMA, CDMA, Bluetooth.TM., IEEE802.11[[b]]a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DMB.

20. A method of improving isolation between a first antenna and a second antenna of a handheld device, the method comprising:

the first antenna operating in a plurality of frequency bands, said first antenna being capable of transmitting and receiving electromagnetic wave signals in each frequency band of said plurality of frequency bands;

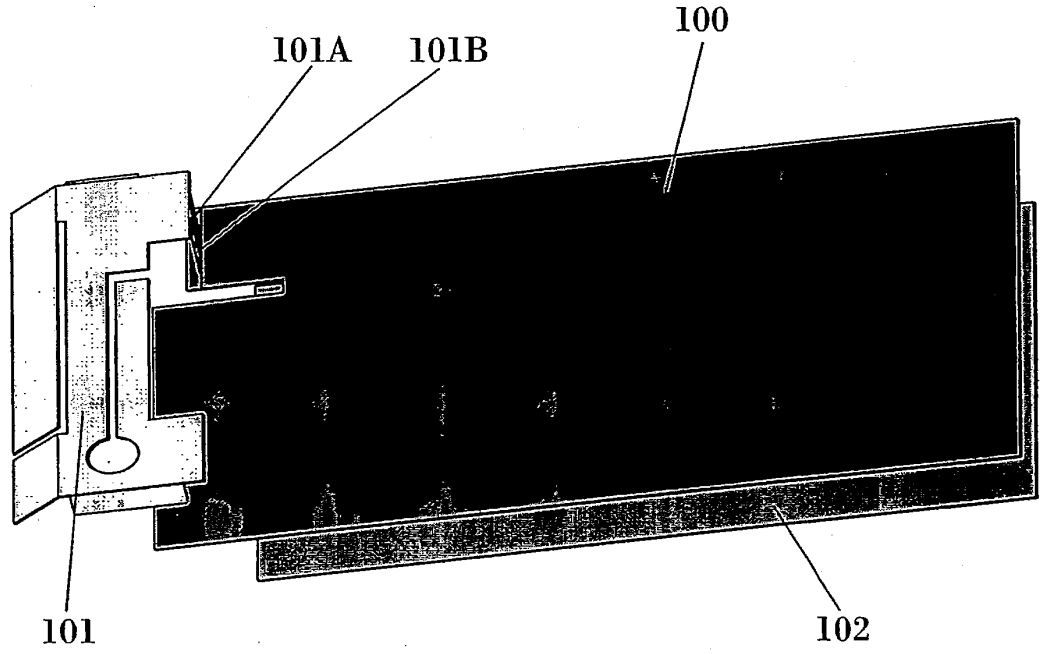
the second antenna operating in a first frequency band, wherein the first frequency band is different from any frequency band of the plurality of frequency bands;

establishing at least one slot in a ground-plane of said handheld device so as to provide for enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna; and

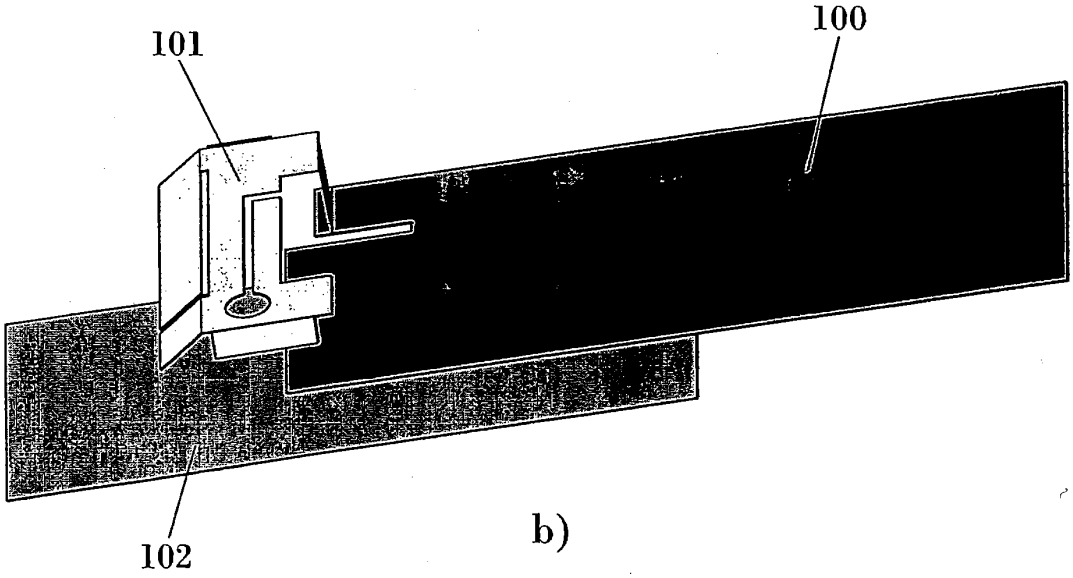
providing a high impedance path in said ground-plane between said feeding points at at least one frequency band selected from said plurality of frequency bands and the first frequency band.

ABSTRACT

The invention relates to a handheld device comprising a first antenna (401, 701, 901, 931, 961, 1101, 1151, 1301, 1501) arranged to operate in at least a first frequency band, and a second antenna (402, 702, 902, 1102, 1302, 1502, 2210) arranged to operate in at least a second frequency band, wherein said second frequency band is different from said first frequency band. According to the invention, the second antenna comprises a slot antenna comprising at least one slot in at least one conductive layer. The invention also relates to enhancement of the isolation between first and second antennas in a handheld device.



a)



b)

FIG. 1
(PRIOR ART)

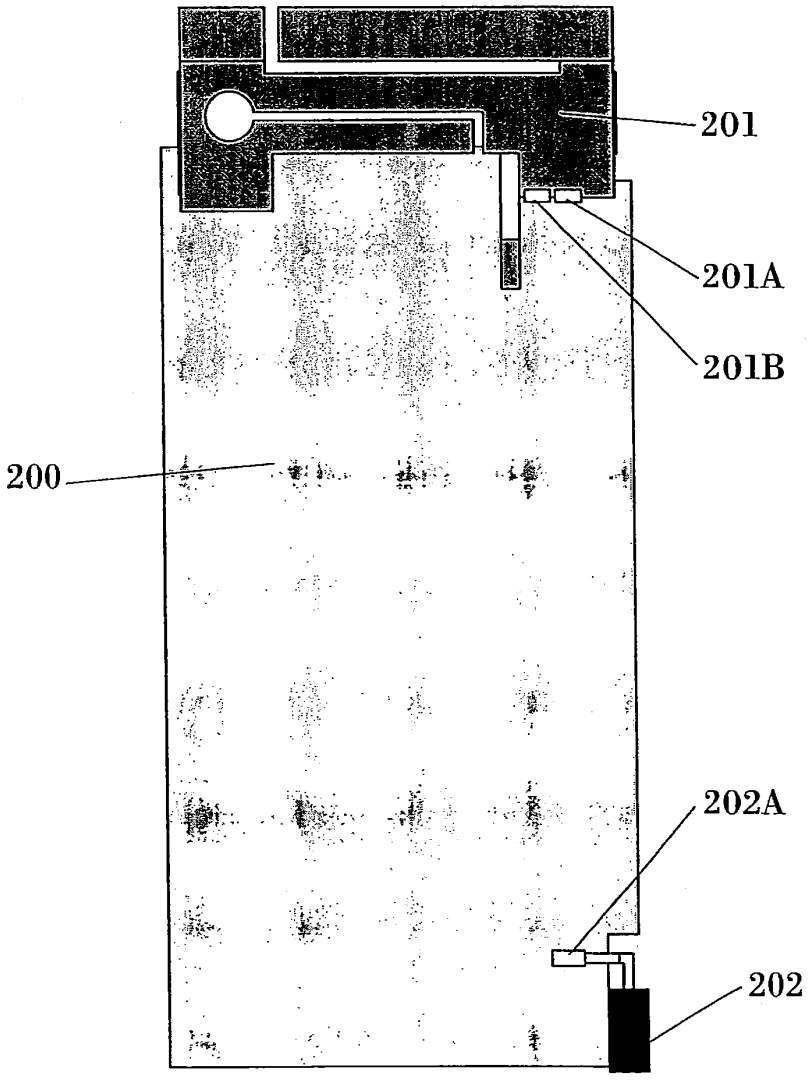
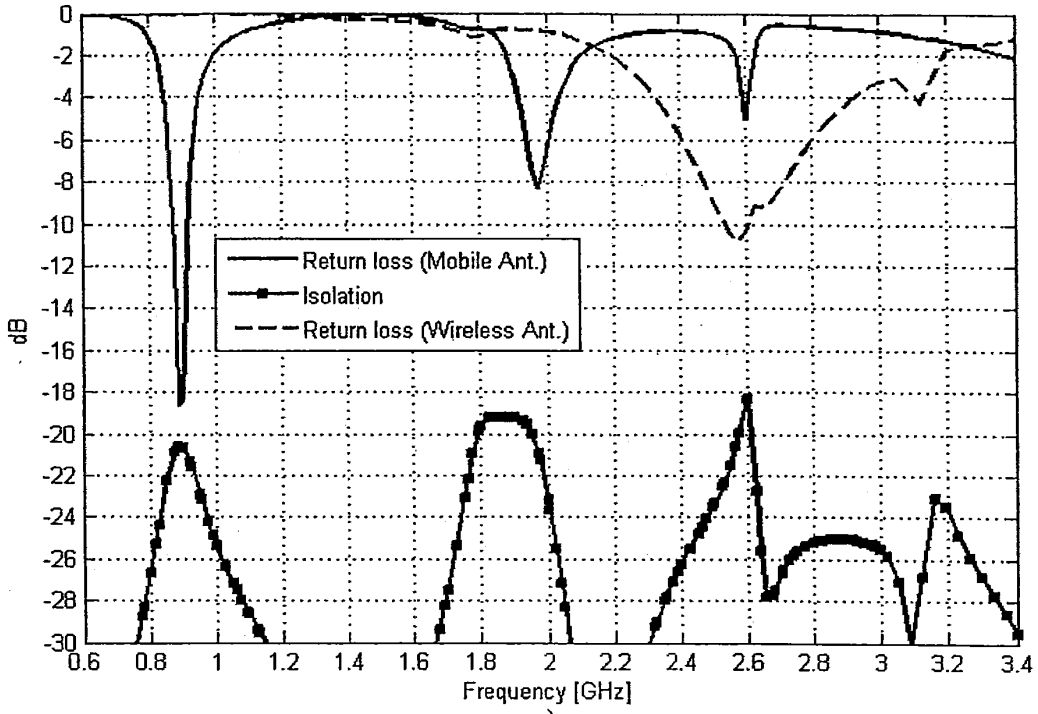
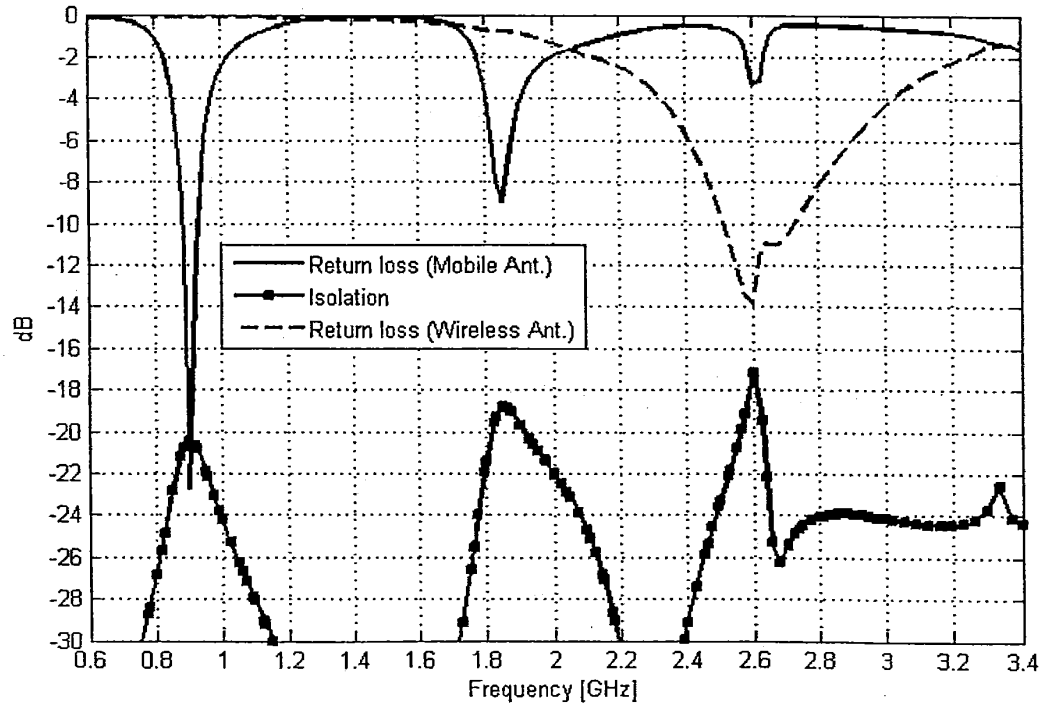


FIG. 2
(PRIOR ART)



a)



b)

FIG. 3
(PRIOR ART)

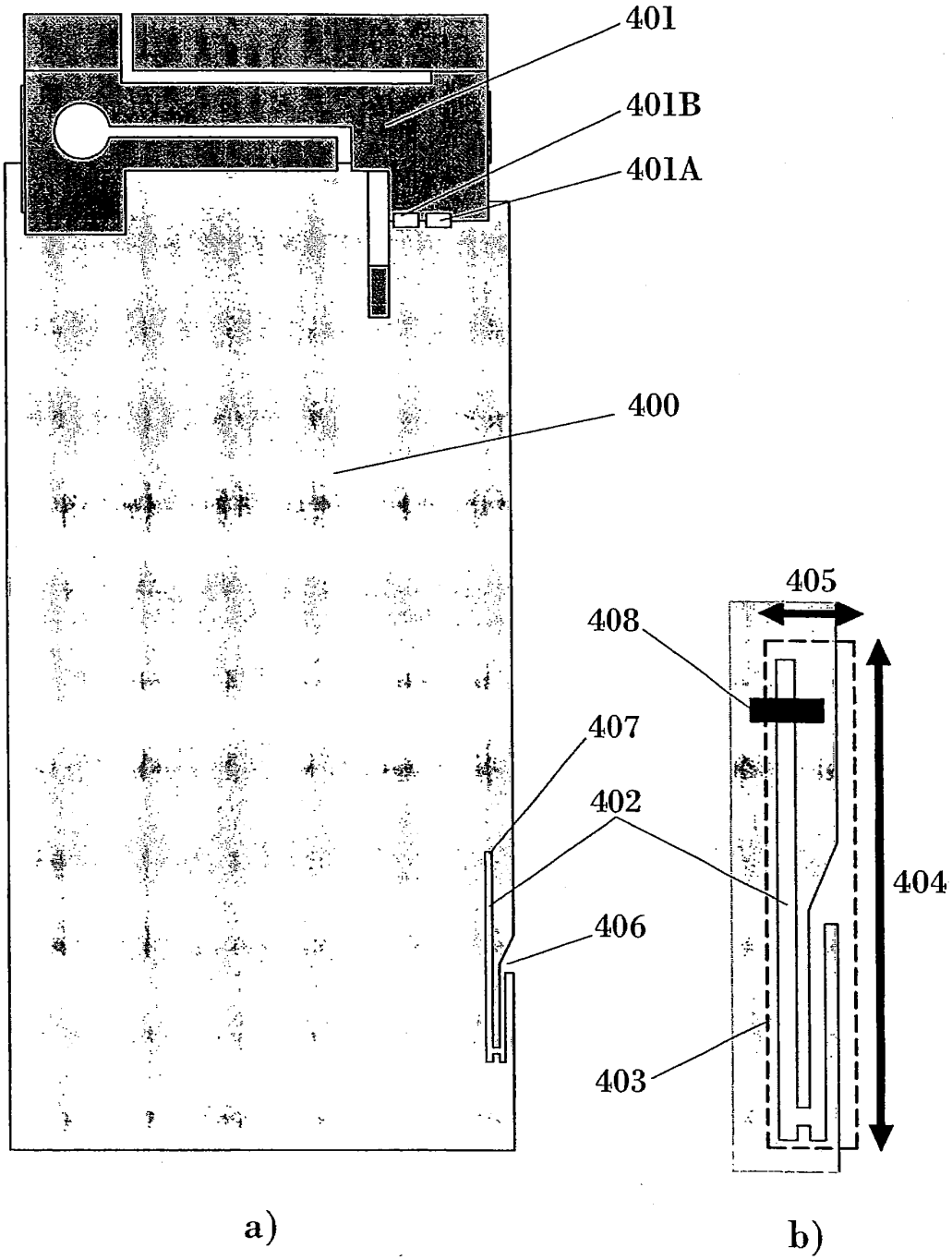
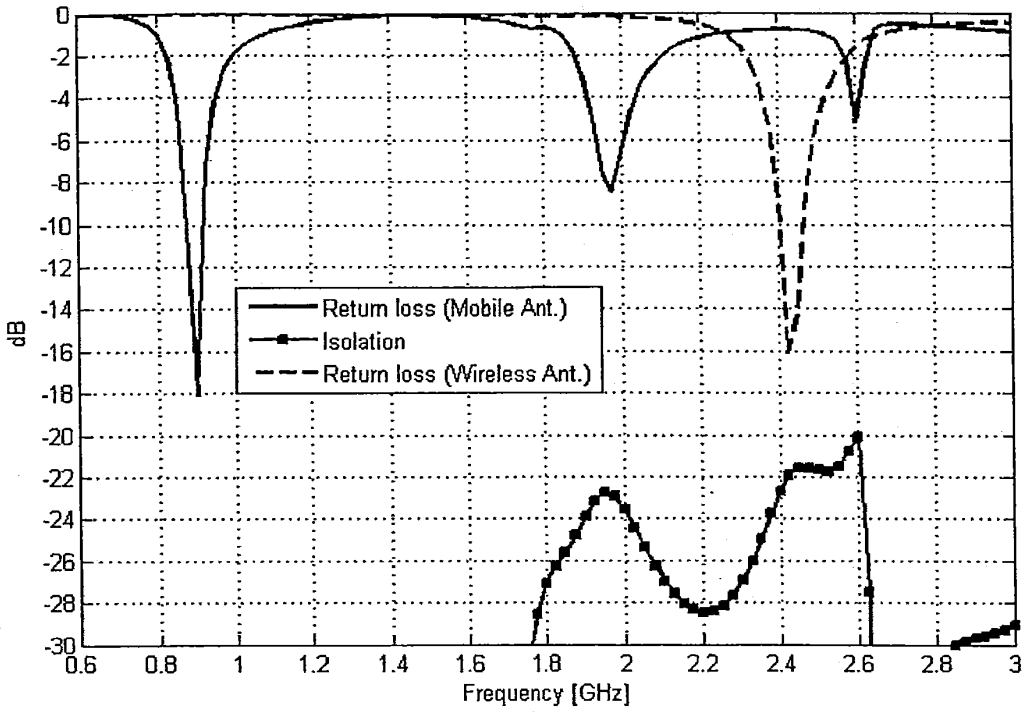
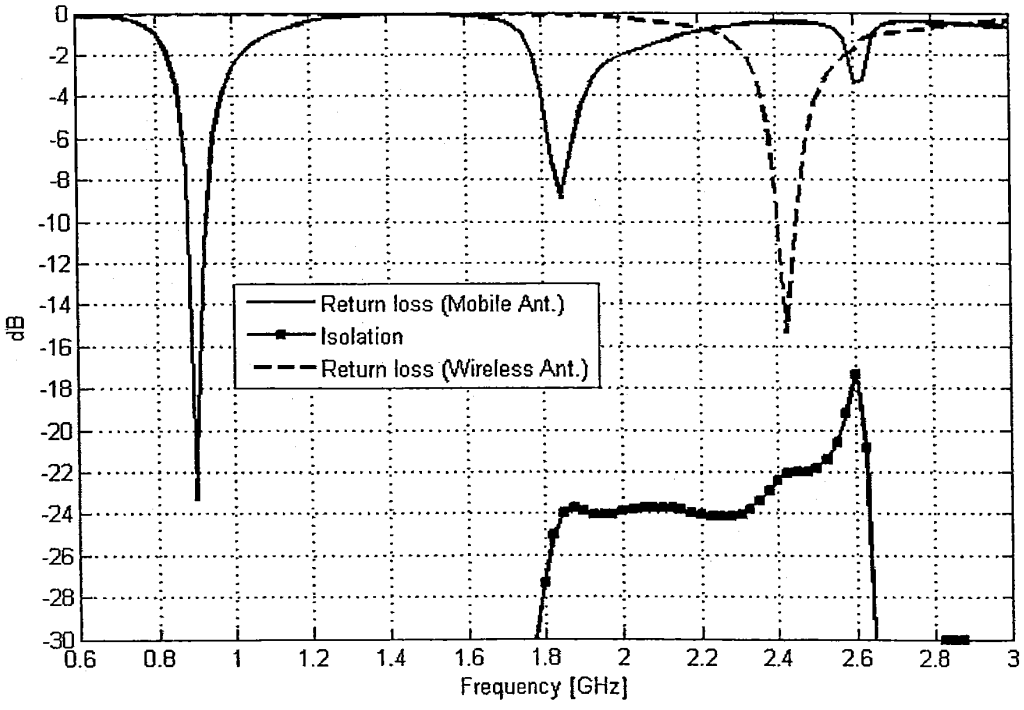


FIG. 4


0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
dB
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Frequency [GHz]
Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)

a)


0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
dB
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
Frequency [GHz]
Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)

b)

FIG. 5

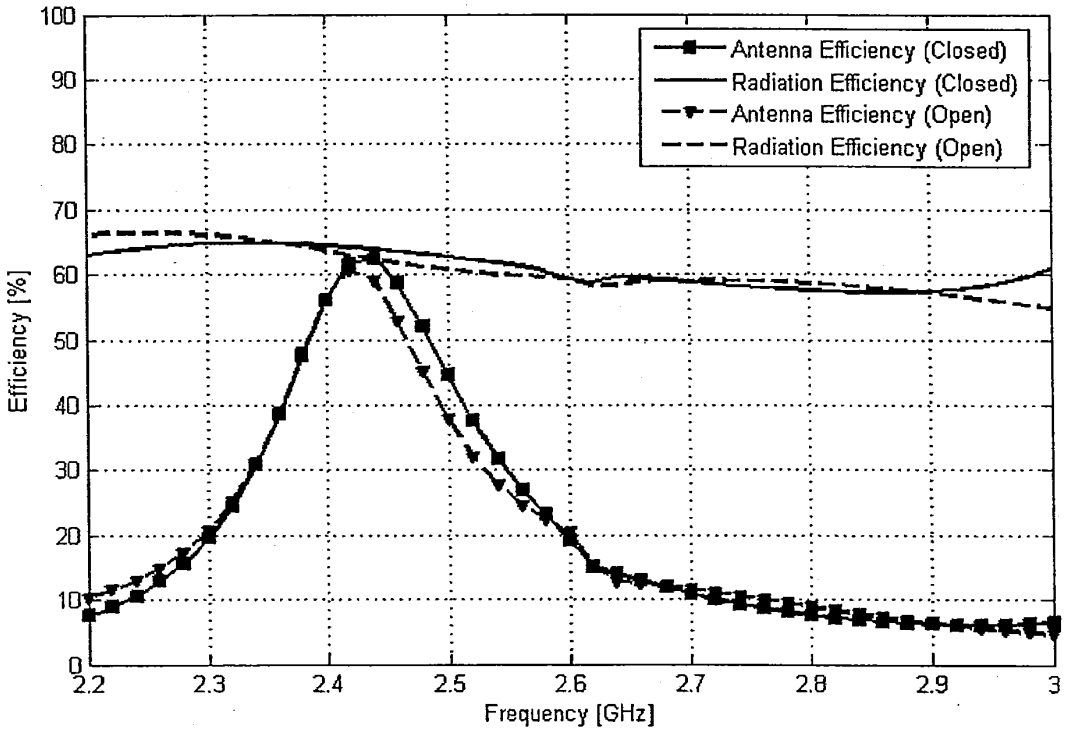

Antenna Efficiency (Closed)
Radiation Efficiency (Closed)
Antenna Efficiency (Open)
Radiation Efficiency (Open)
Efficiency [%]
Frequency [GHz]
100
90
80
70
60
50
40
30
20
10
0
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3

FIG. 6

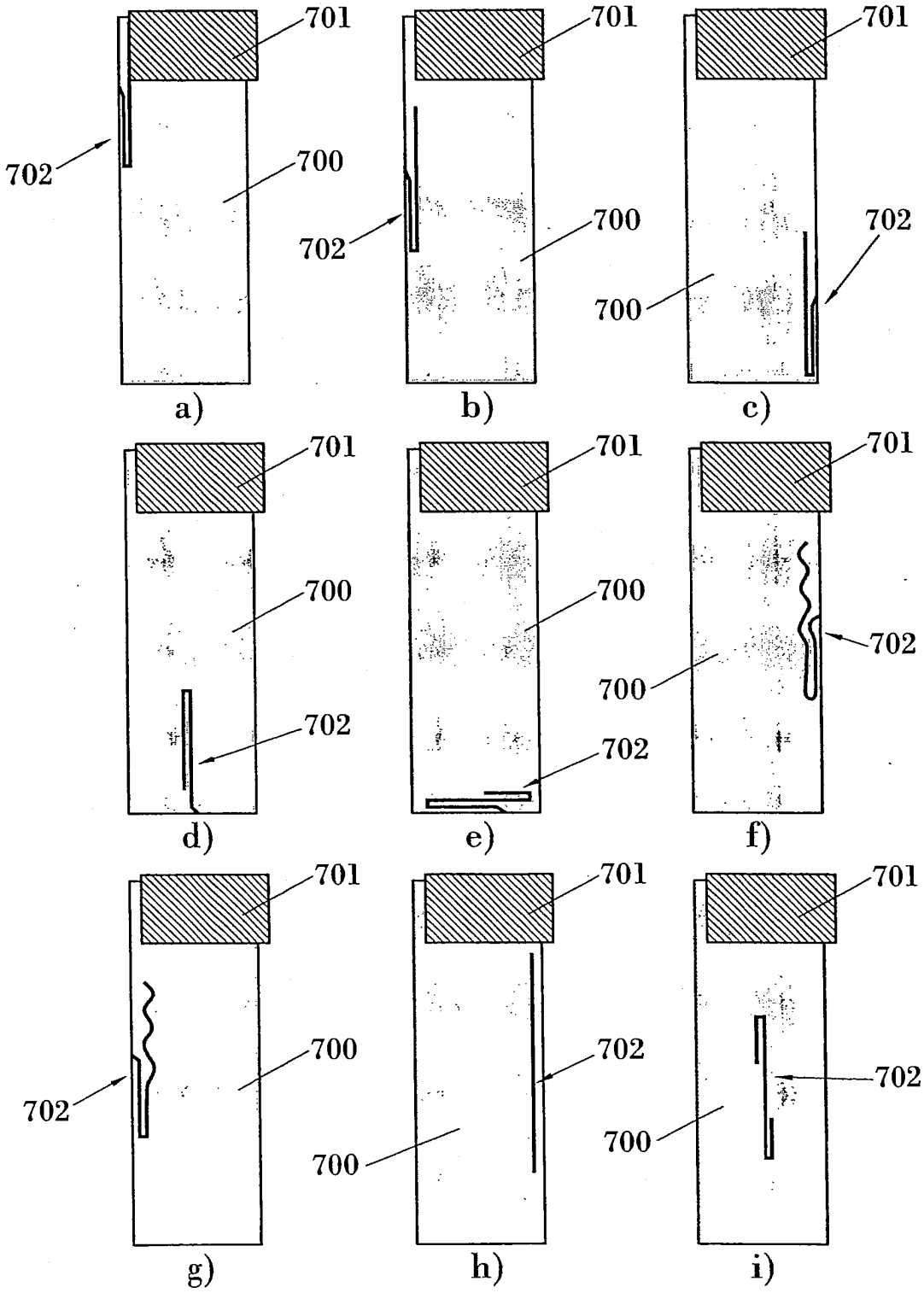
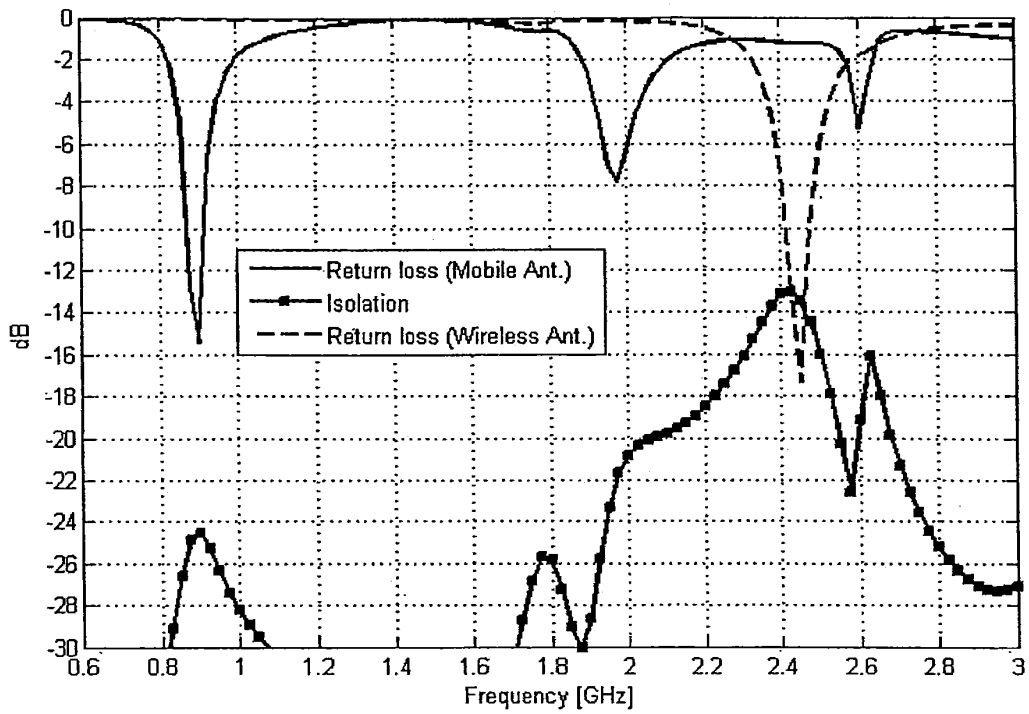
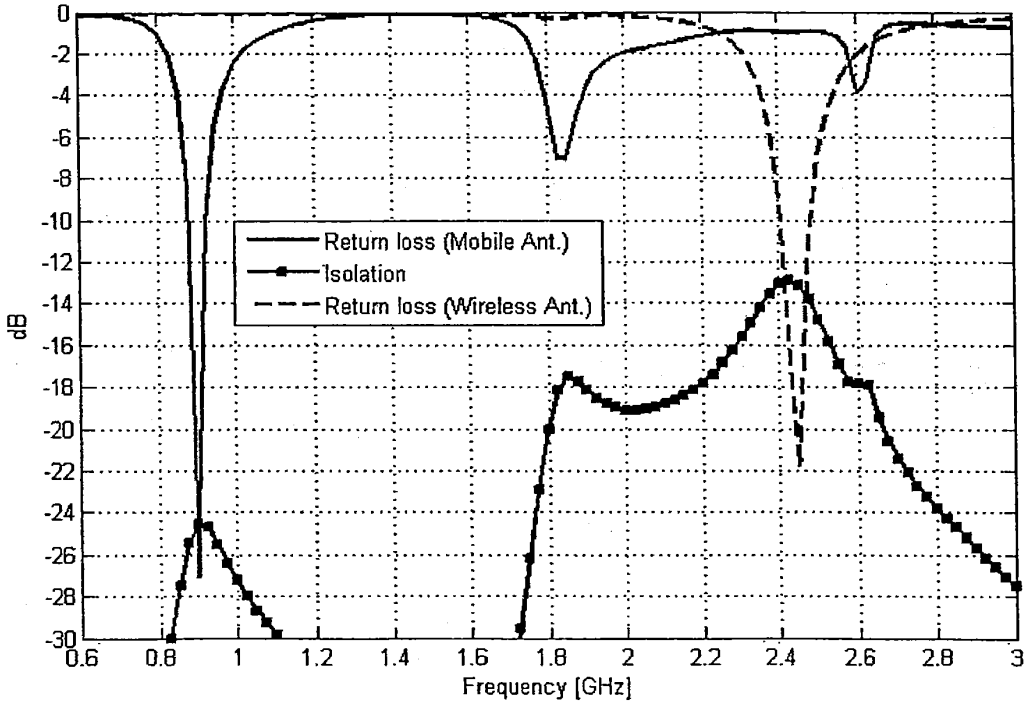


FIG. 7


Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)
dB
Frequency [GHz]

a)


Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)
dB
Frequency [GHz]

b)

FIG. 8

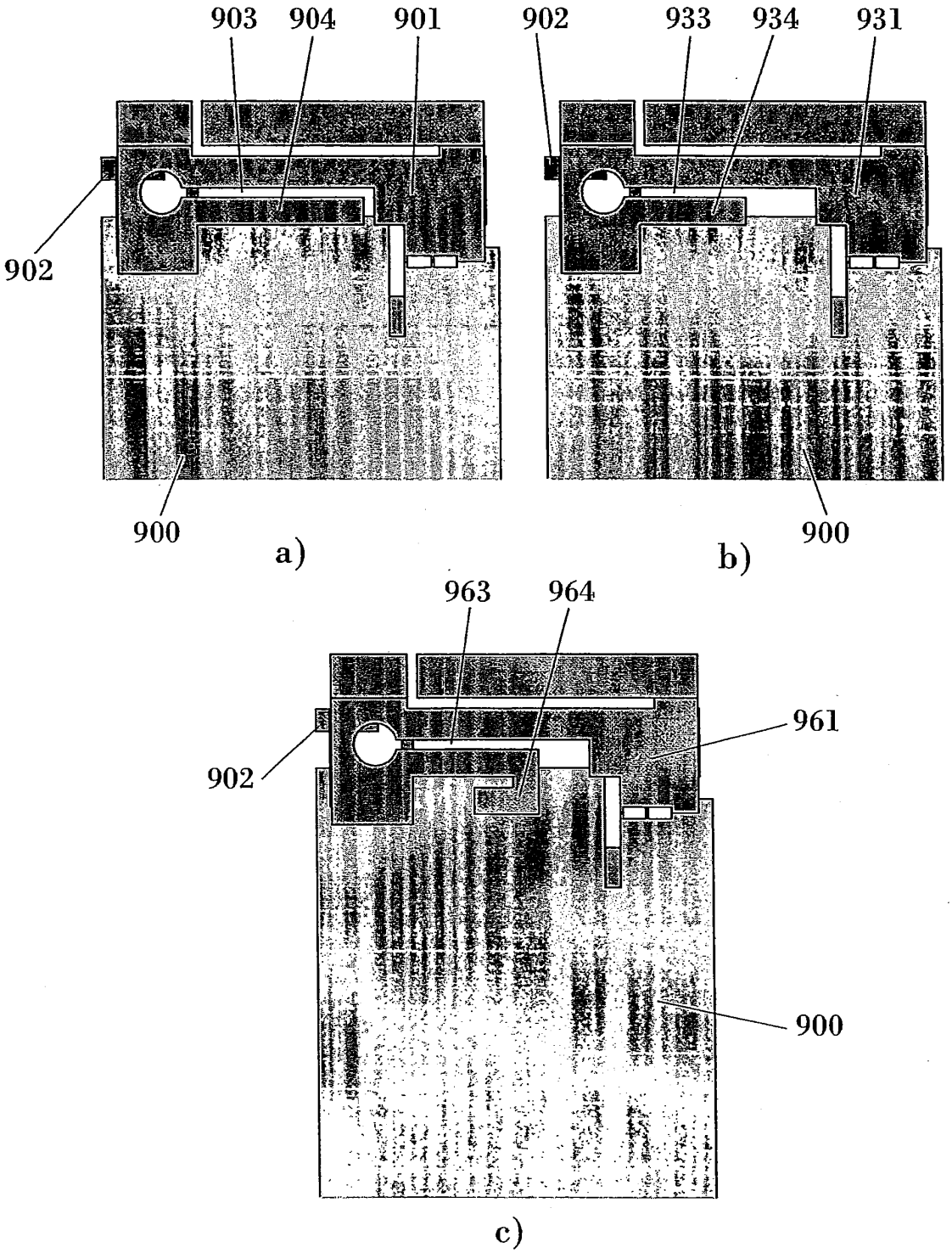


FIG. 9

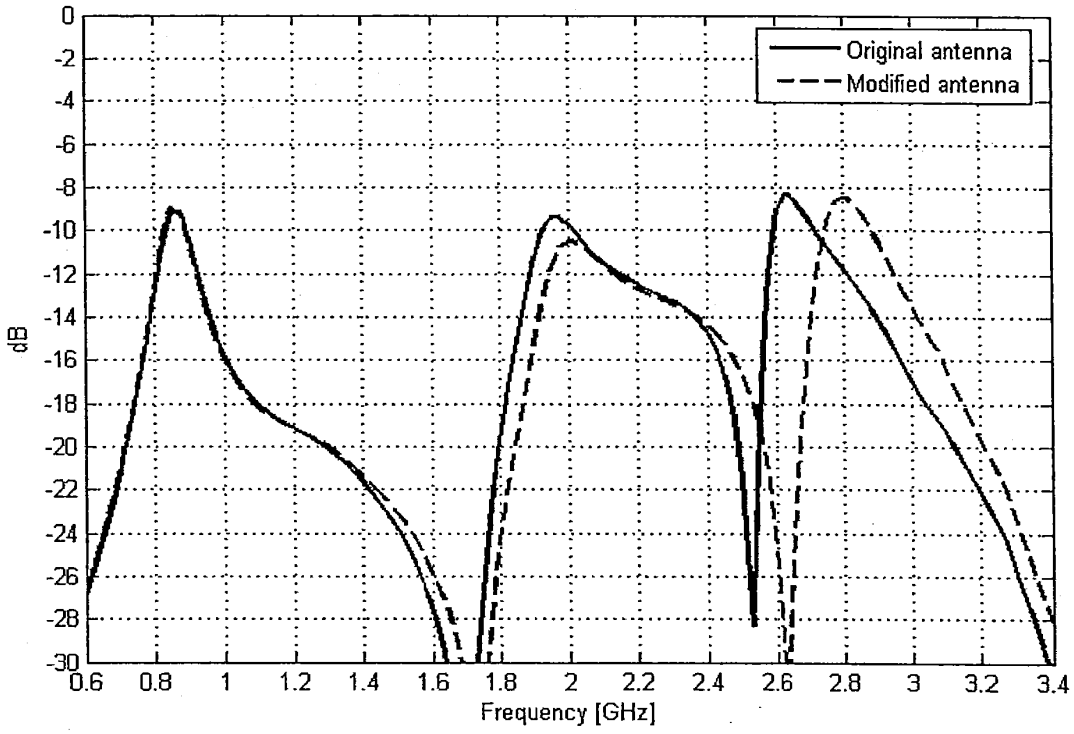
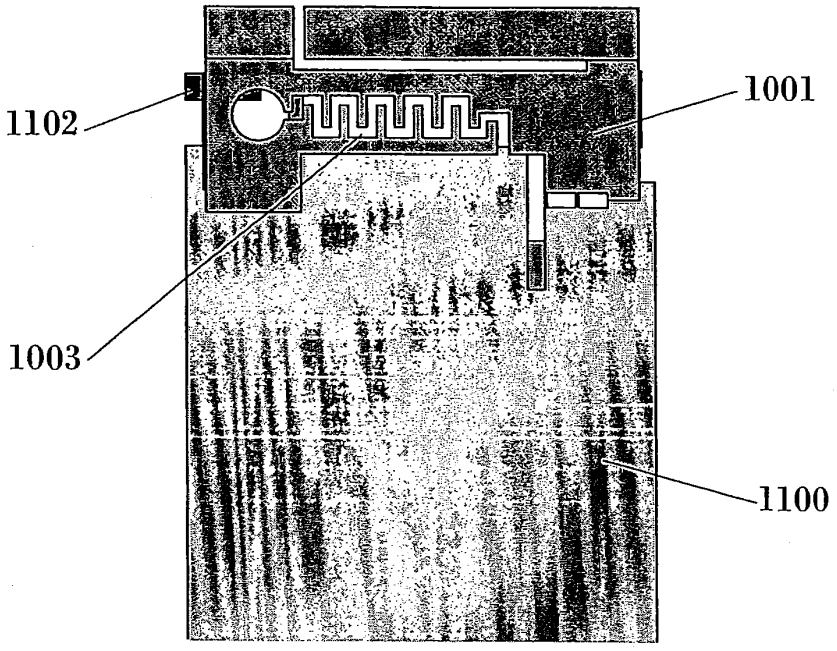
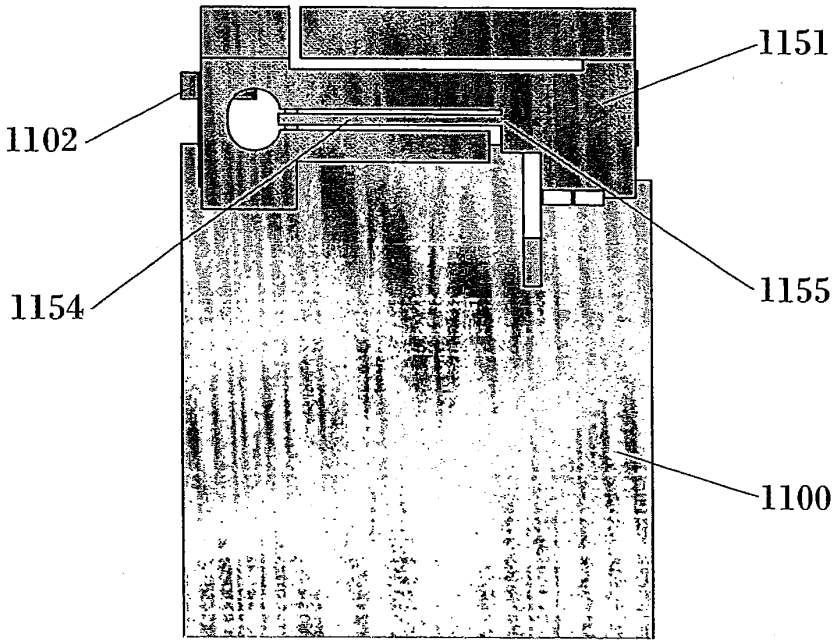

Original antenna
Modified antenna
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 10



a)



b)

FIG. 11

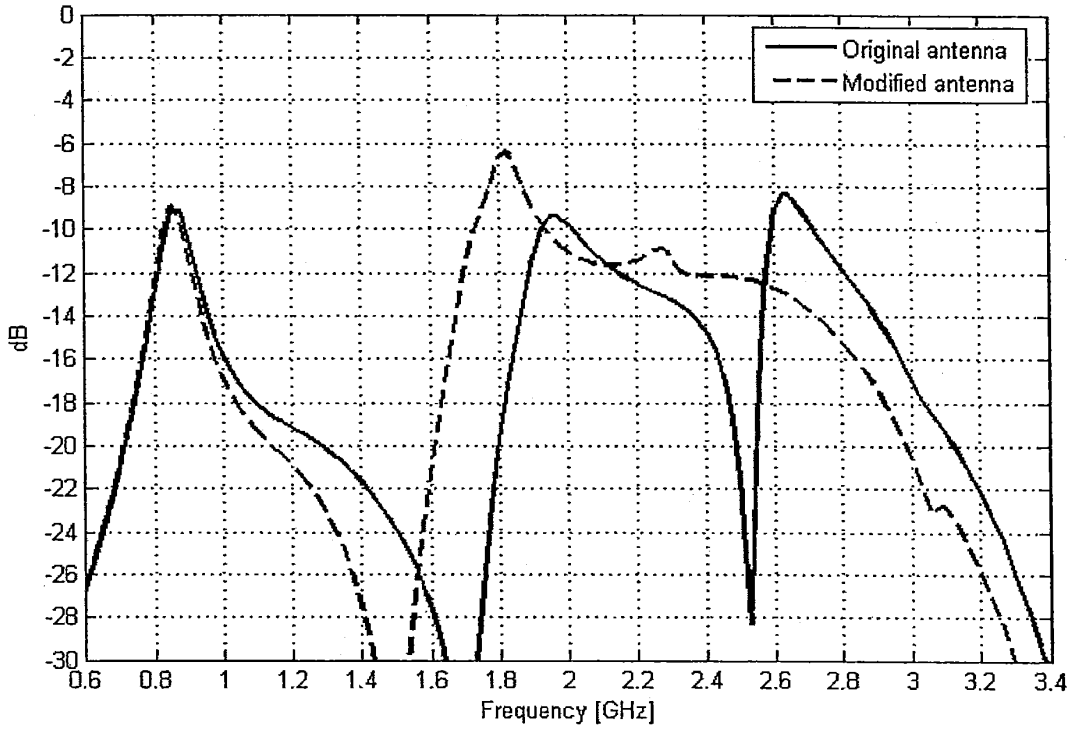
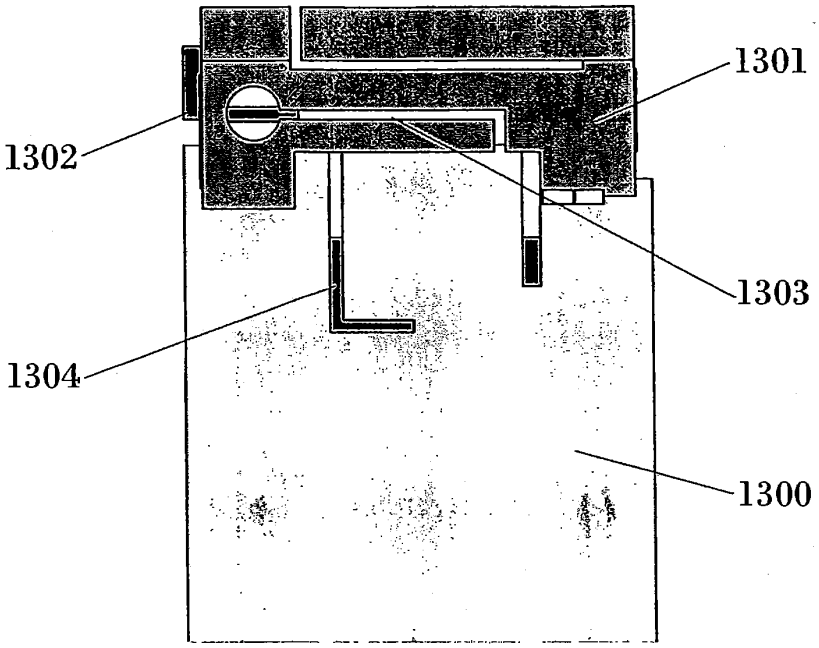
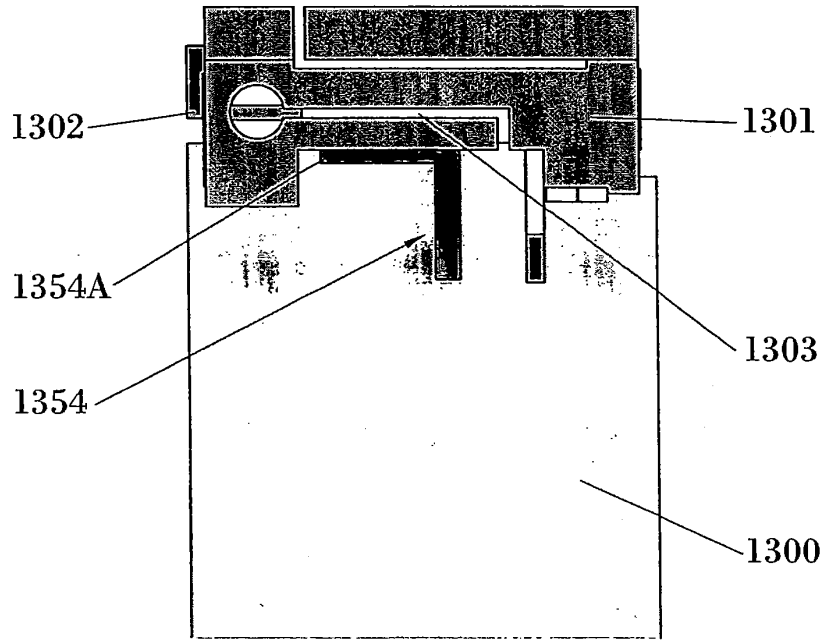

Original antenna
Modified antenna
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 12



a)



b)

FIG. 13

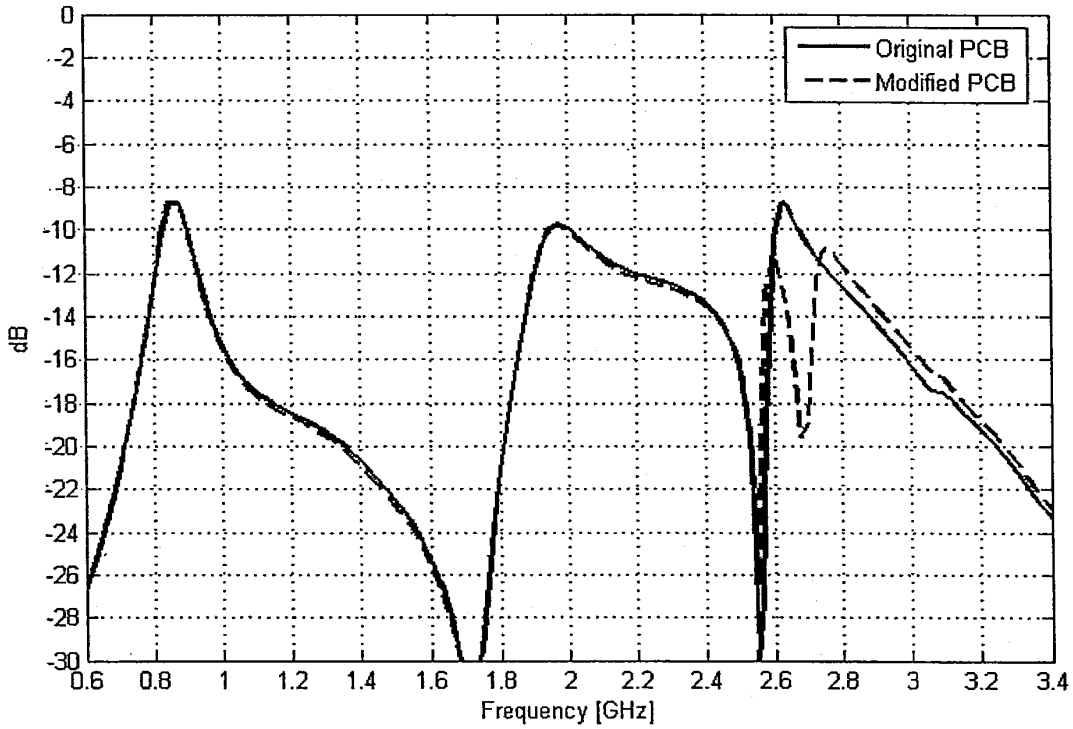
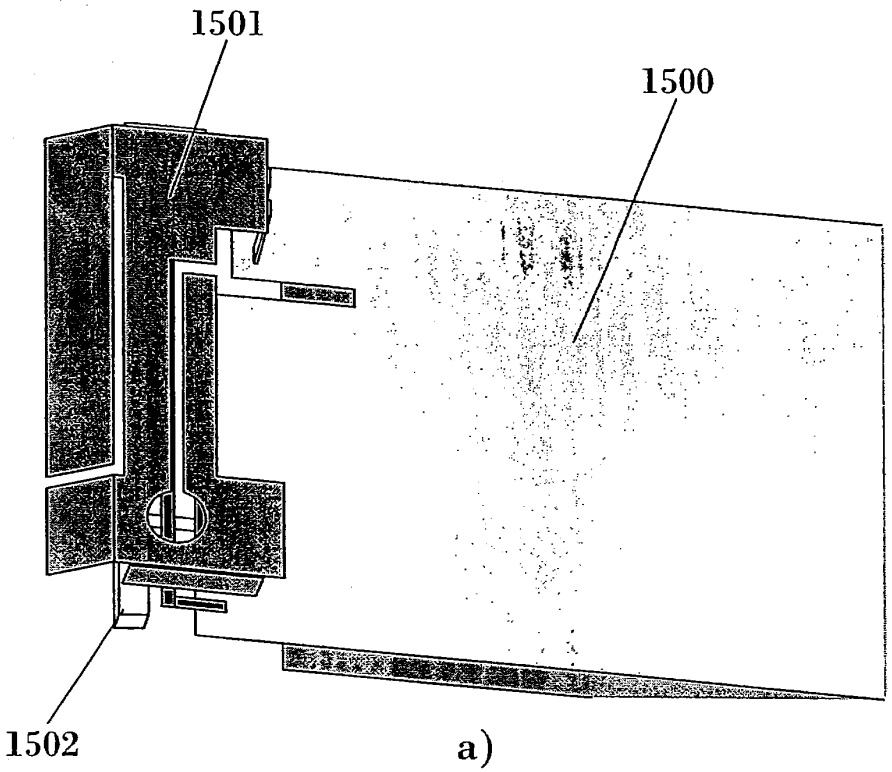
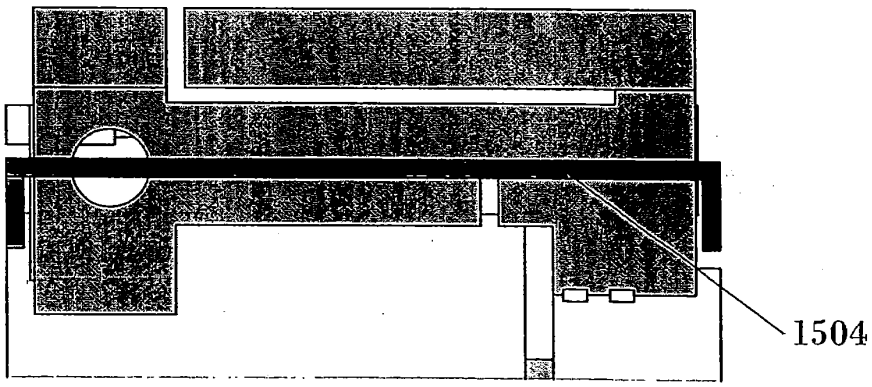

Original PCB
Modified PCB
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 14



a)



b)

FIG. 15

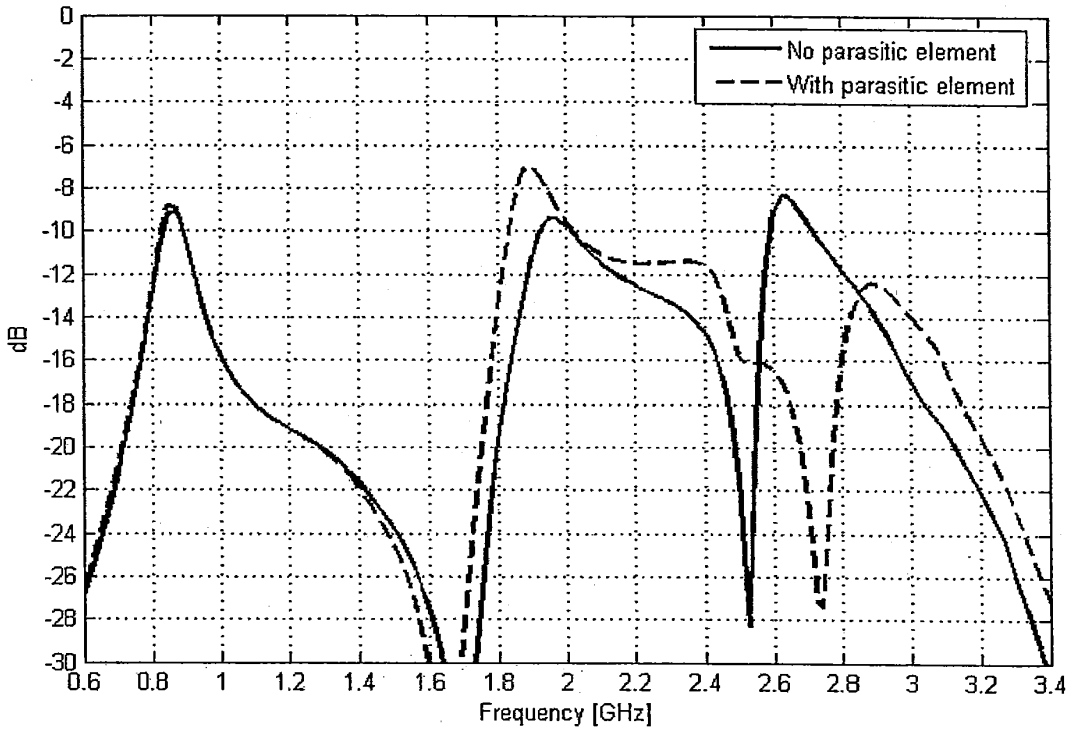

No parasitic element
With parasitic element
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 16

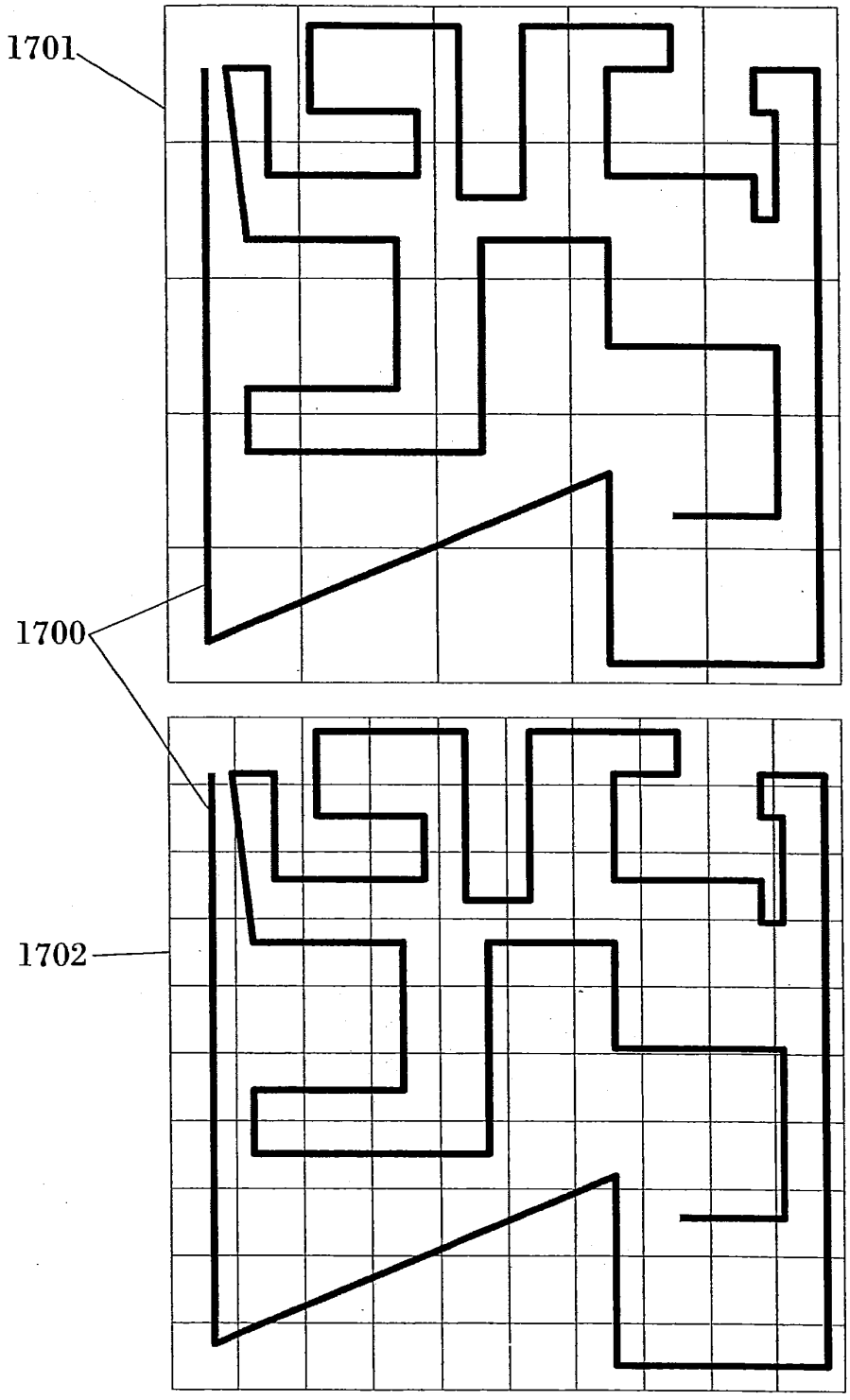


FIG. 17

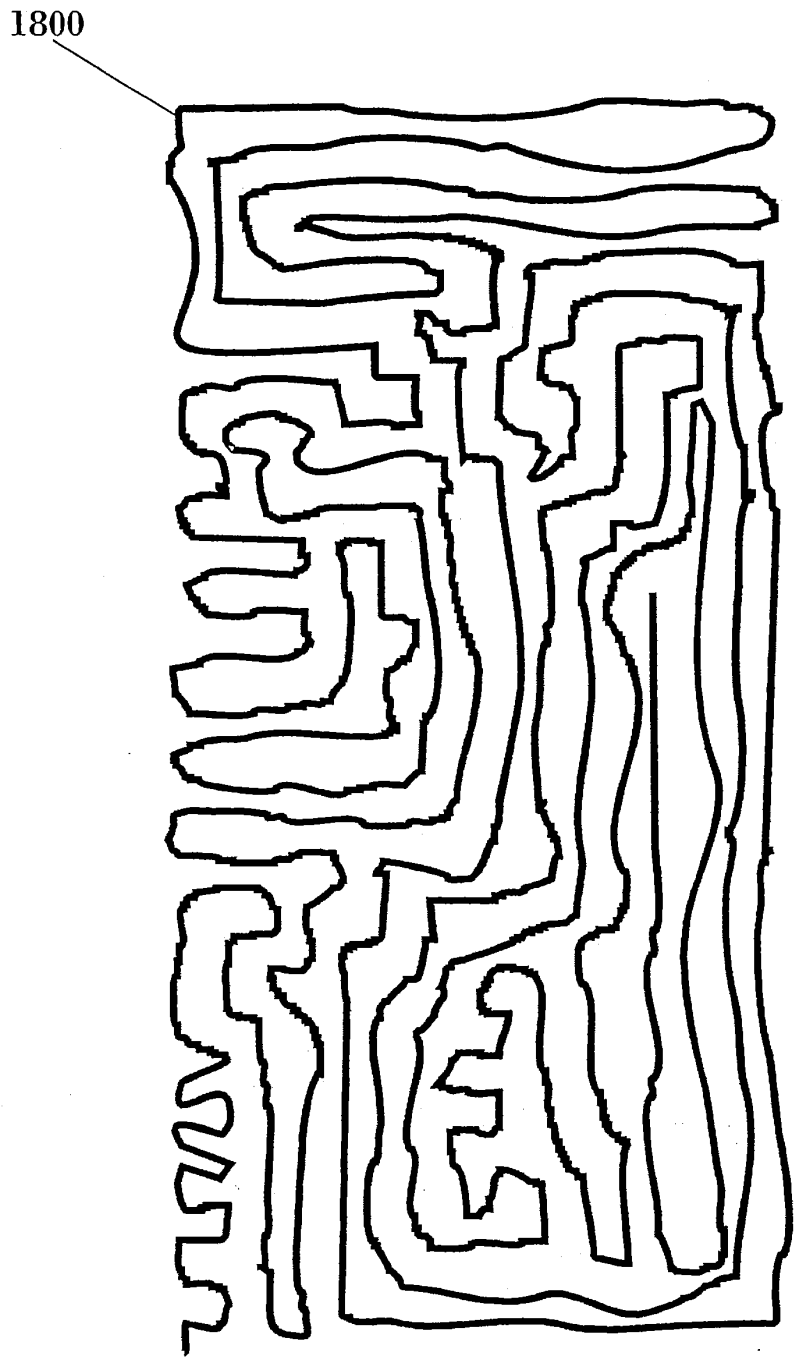


FIG. 18

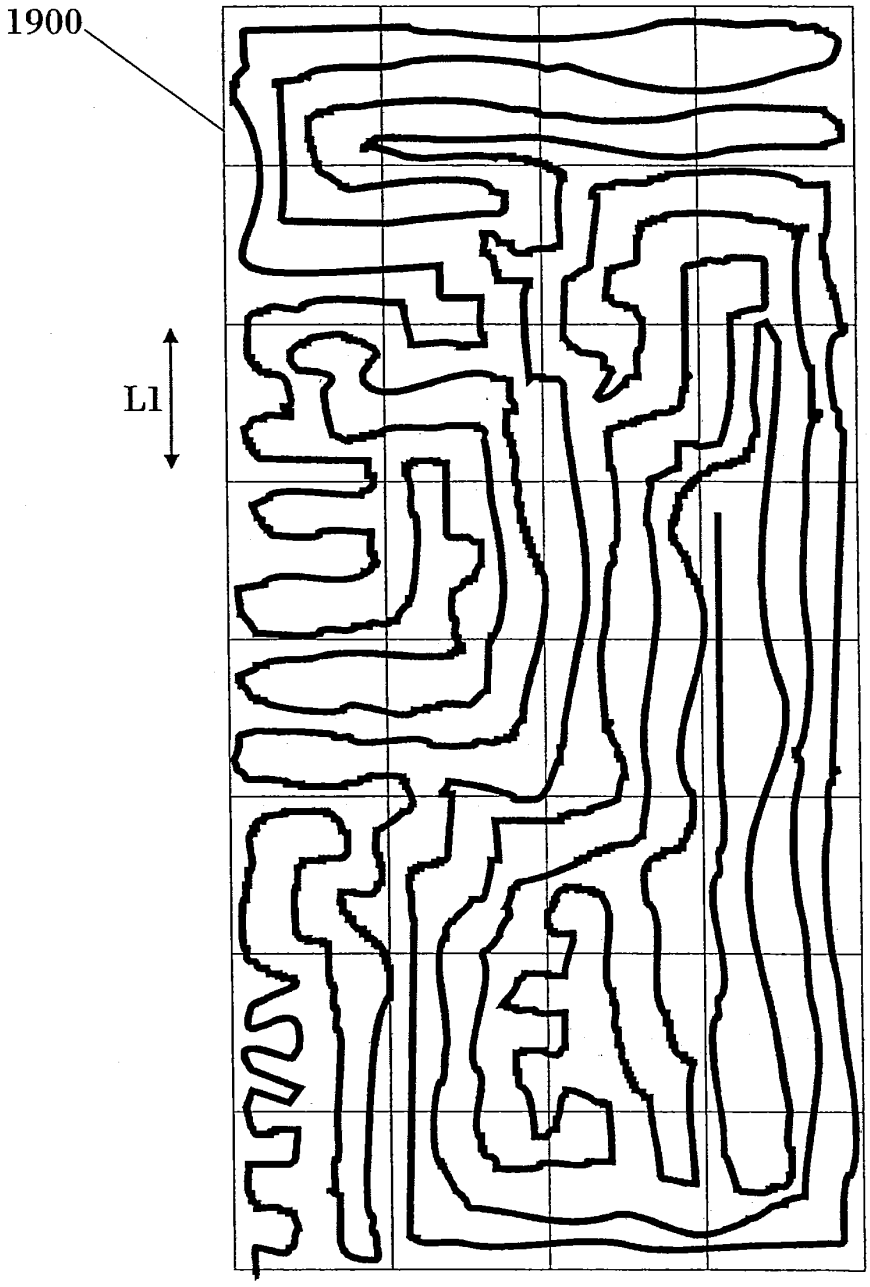


FIG. 19

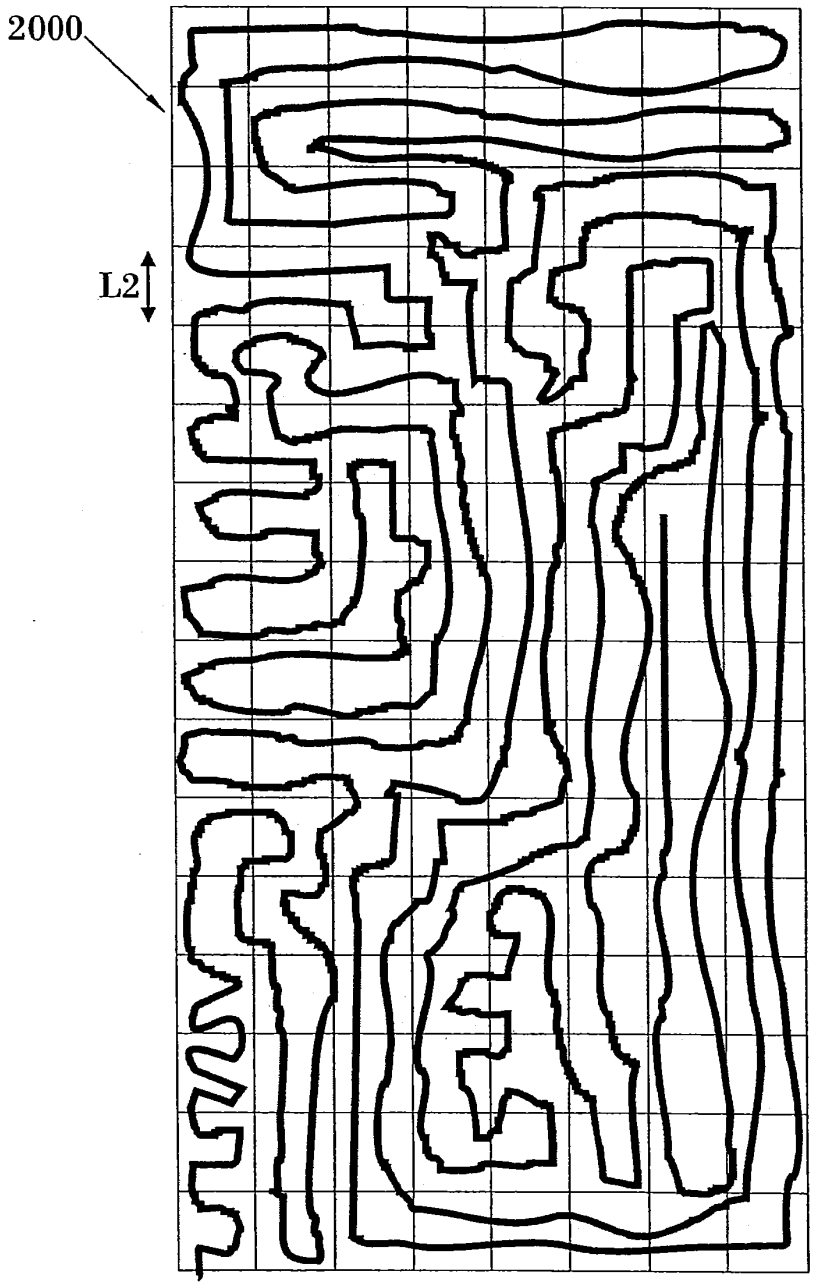


FIG. 20

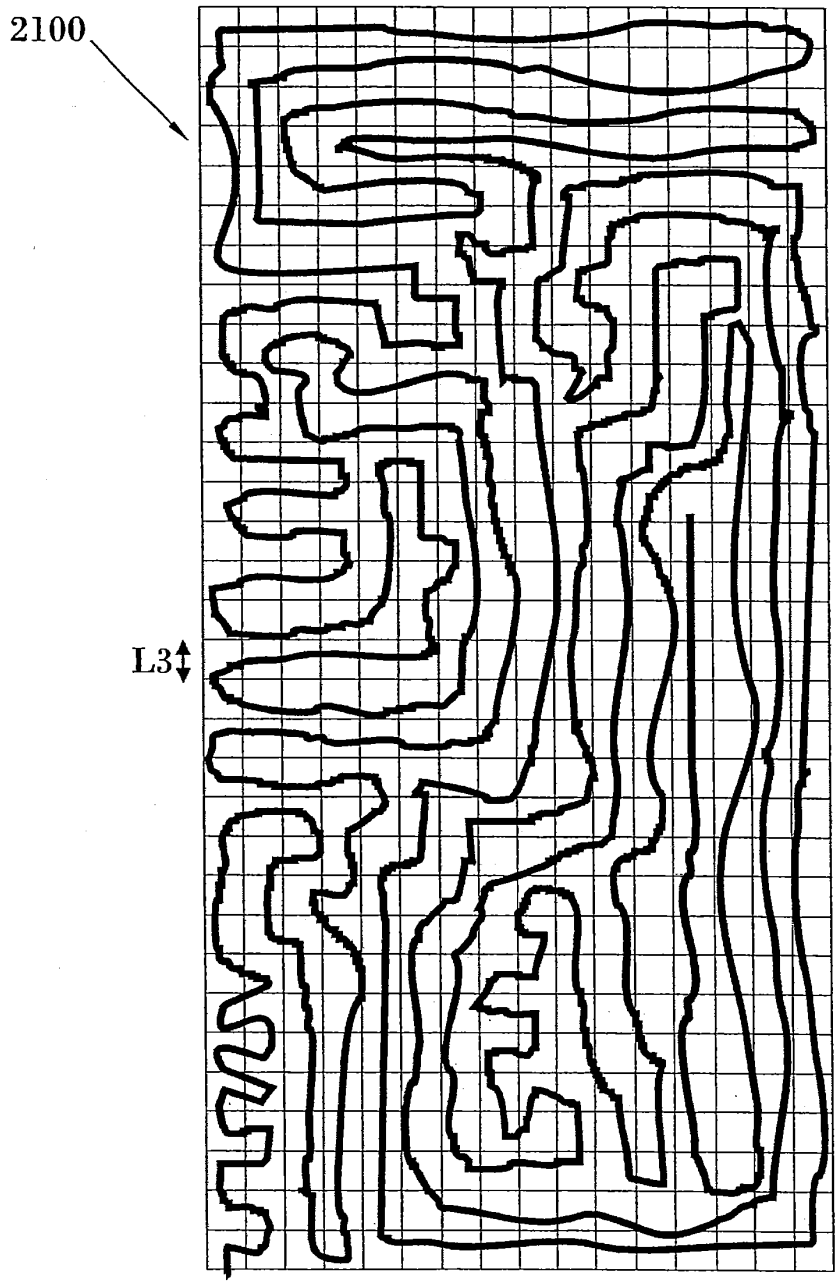


FIG. 21

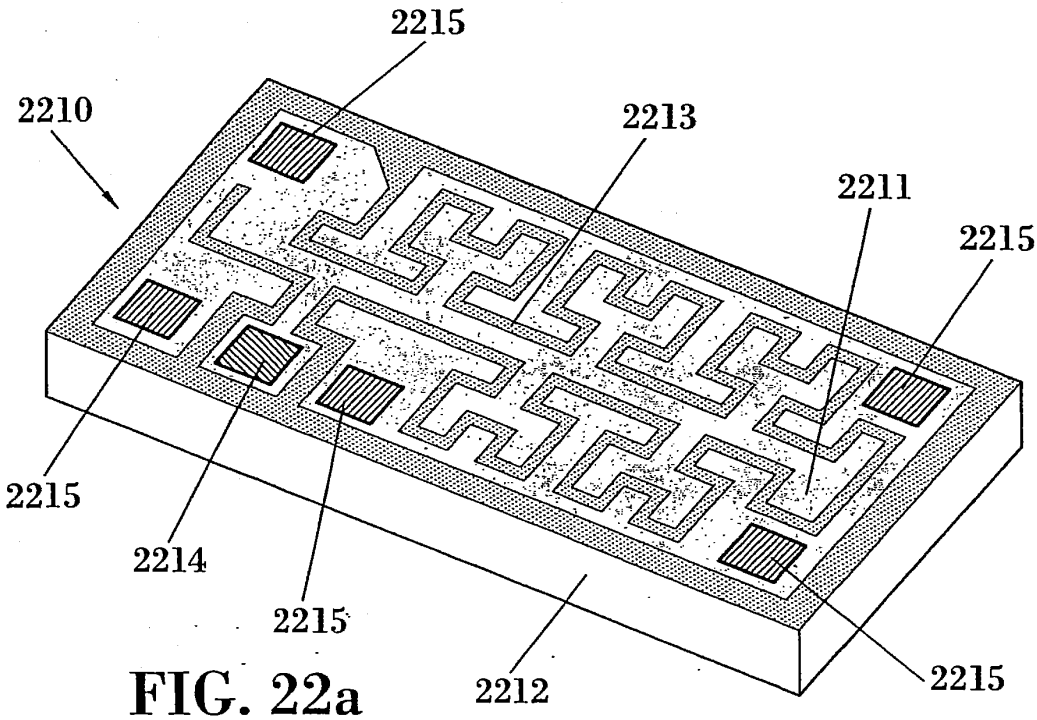


FIG. 22a

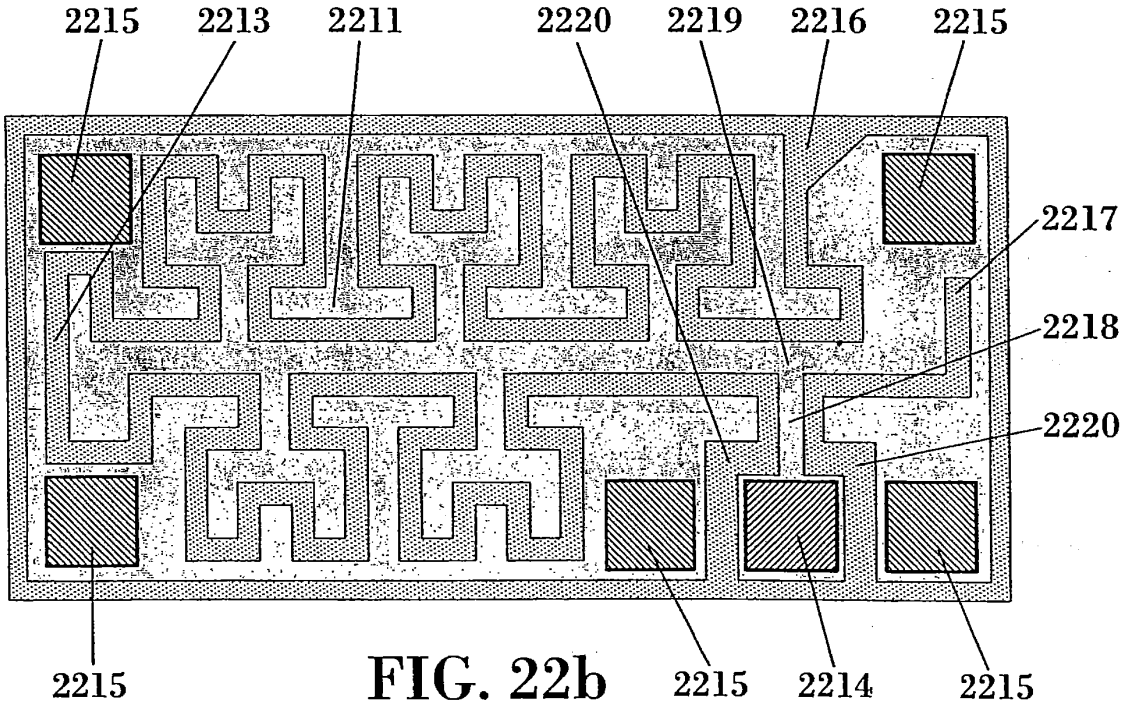


FIG. 22b

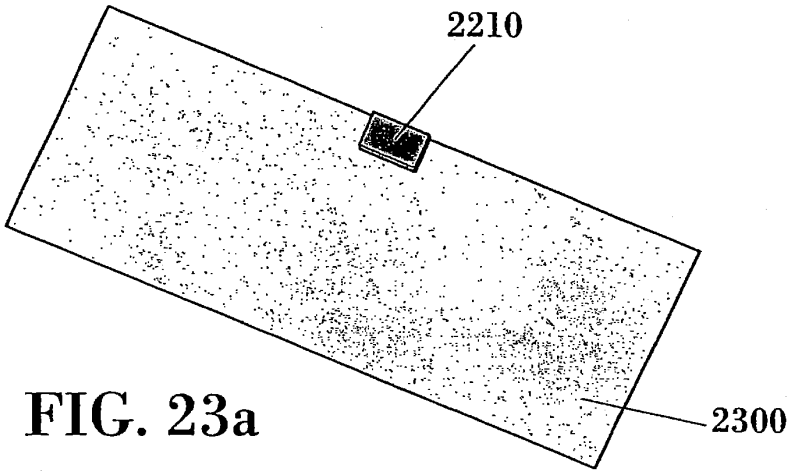


FIG. 23a

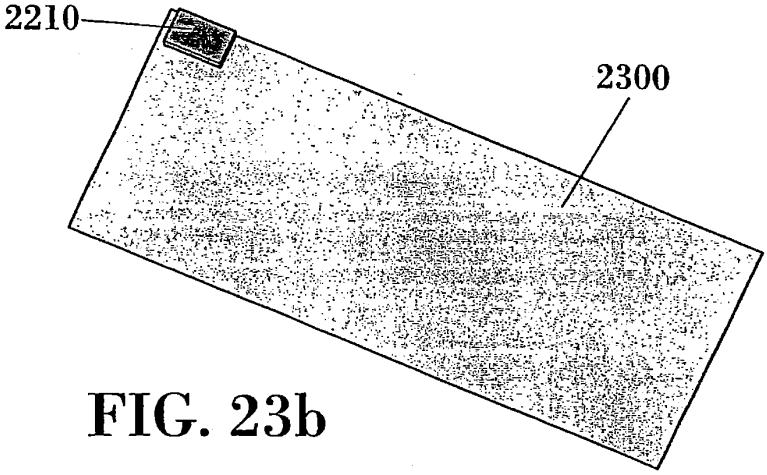


FIG. 23b

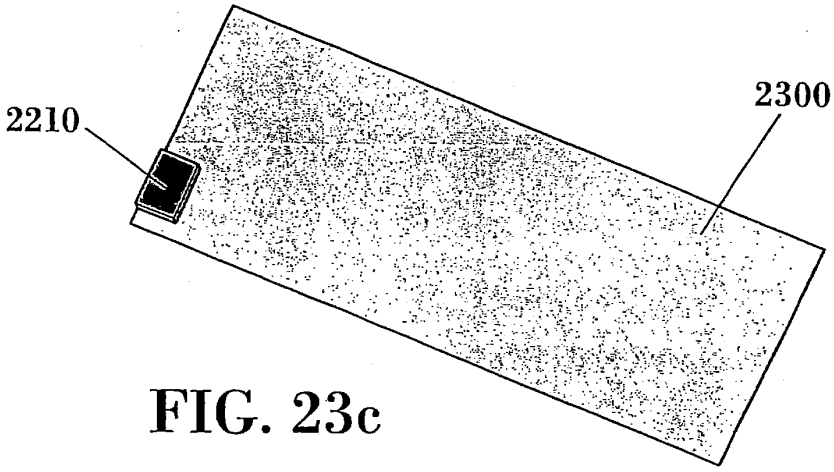


FIG. 23c

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled:

HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS

the specification of which was filed on July 18, 2006 as Application No. PCT/EP2006/007050.

In the event that the filing date and/or Application No. are not entered above at the time I execute this document, and if such information is deemed necessary, I hereby authorize and request my attorneys/agent(s) at **Winstead PC**, P.O. Box 50784, Dallas, Texas 75201, to insert above the filing date and/or Application No. of said application.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment, if any, specifically referred to herein.

I acknowledge the duty to disclose all information known to me that is material to patentability in accordance with Title 37, Code of Federal Regulations, § 1.56.

FOREIGN PRIORITY CLAIM

I hereby claim foreign priority benefits under Title 35, United States Code § 119(a)-(d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

☐ no such foreign applications have been filed

☒ such foreign application have been filed as follows:

EARLIEST FOREIGN APPLICATION(S), IF ANY FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS U.S. APPLICATION

Application Number	Country	Date of Filing	Priority Claimed Under 35 USC 119
05106694.2	EP	July 21, 2005	X Yes No

ALL FOREIGN APPLICATION(S), IF ANY FILED MORE THAN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO THIS U.S. APPLICATION

Application Number	Country	Date of Filing

CLAIM FOR BENEFIT OF EARLIER U.S. PROVISIONAL APPLICATIONS

I hereby claim priority benefits under Title 35, United States Code §119(e), of any United States provisional patent application(s) listed below:

☐ no such U.S. provisional applications have been filed.

☒ such U.S. provisional application have been filed as follows:

Application Number	Date of Filing	Priority Claimed Under 35 USC 119
60/702,205	July 25, 2005	X Yes No

CLAIM FOR BENEFIT OF EARLIER U.S./PCT APPLICATION(S)

I hereby claim the benefit under Title 35, United States Code, §120 of the United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose all information that is material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56 which became available to me between the filing date of the prior application and the national or PCT international filing date of this application:

☒ no such U.S./PCT applications have been filed.

☐ such U.S./PCT application have been filed as follows:

Application Number	Relationship	Parent Application	Date of Filing

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint:

All practitioners at Customer Number 61060

all of **Winstead PC**, P.O. Box 50784, Dallas, Texas 75201, jointly, and each of them severally, my attorneys at law/patent agent(s), with full power of substitution, delegation and revocation, to prosecute this application, to make alterations and amendments therein, to receive the patent, and to transact all business in the U. S. Patent and Trademark Office connected therewith.

The undersigned hereby authorizes the U.S. attorney or agent named herein to accept and follow instructions from Fractus, S.A. as to any action to be taken in the United States Patent and Trademark Office regarding this application without direct communication between the U.S. attorney or agent and the undersigned. In the event of a change in the persons from whom instructions may be taken, the U.S. attorney or agent named herein will be so notified by the undersigned.

Please mail all correspondence to Stanley R. Moore, whose address is:

Winstead PC
P.O. Box 50784
Dallas, Texas 75201

Please direct telephone calls to: Stanley R. Moore at (214) 745-5110.

Please direct facsimiles to: (214) 745-5390

Full name of sole or first inventor Josep Mumbru	
Sole or first inventor's signature	Date Sept. 10, 2008.
Residence Barcelona, Spain	
Citizenship Spain	
Mailing Address Rector Ubach, 25, 2° 1ª 08021 Barcelona SPAIN	

Full name of second inventor, if any Jaume Anguera	
Second inventor's signature	Date 9 Sept 2008
Residence Castellon, Spain	
Citizenship Spain	
Mailing Address Paseo Blasco Ibañez 15-2, Vinaros E-12500 Castellon SPAIN	

Full name of third inventor, if any Jordi Soler	
Third inventor's signature	Date 8 Sept 2008
Residence Girona, Spain	
Citizenship Spain	
Mailing Address Riu Terri 21-23 3er E-17003 Girona SPAIN	

Full name of fourth inventor, if any Carles Puente	
Fourth inventor's signature	Date 9th SEPT 2009
Residence Barcelona, Spain	
Citizenship Spain	
Mailing Address Alcalde Barnils, 64-68 Modul C, 3a pl. E-08174 Sant Cugat del Valles SPAIN	

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/341,051

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	380
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	620
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	250
TOTAL CLAIMS (37 CFR 1.16(i))	20 minus 20 =	*			OR	x 60 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*				x 250 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1250

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

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United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/341,051	12/30/2011	2821	1250	47005-P040WUSC1	20	3

CONFIRMATION NO. 9540

61060
WINSTEAD PC
P.O. BOX 50784
DALLAS, TX 75201

FILING RECEIPT

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Date Mailed: 01/13/2012

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Domestic Priority data as claimed by applicant

This application is a CON of 11/988,888 09/30/2008
which is a 371 of PCT/EP2006/007050 07/18/2006
which claims benefit of 60/702,205 07/25/2005

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)
EUROPEAN PATENT OFFICE (EPO) 05106694.2 07/21/2005

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Projected Publication Date: 04/26/2012

Non-Publication Request: No

Early Publication Request: No

Title

HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS

Preliminary Class

343

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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Attestation

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécificée à la page suivante.

Patentanmeldung Nr. **Patent application No.** **Demande de brevet n°**

05106694.2 / EP05106694

The organization code and number of your priority application, to be used for filing abroad under the Paris Convention, is EP05106694

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le President de l'Office européen des brevets
p.o.

R.C. van Dijk

CB03505

Anmeldung Nr:
Application no.: 05106694.2
Demande no:

Anmeldetag:
Date of filing: 21.07.05
Date de dépôt:

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
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Wireless connectivity antenna for a mobile handset with enhanced isolation

In anspruch genommene Priorität(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen / State/Date/File no. / Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation / International Patent Classification / Classification internationale de brevets:

H01Q

Am Anmeldetag benannte Vertragstaaten / Contracting states designated at date of filing / Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

WIRELESS CONNECTIVITY ANTENNA FOR A MOBILE HANDSET WITH ENHANCED ISOLATION

Object of the invention

The present invention relates to a handset and generally to any handheld device, which includes an antenna for receiving and transmitting electromagnetic wave signals.

It is an object of the present invention to disclose a handset or handheld device (such as for instance a mobile phone, a smartphone, a PDA, a MP3 player, a headset, a USB dongle, a laptop, a PCMCIA or Cardbus 32 card), which comprises a first antenna for mobile communications, and a second antenna for mobile communications, or for at least a wireless connectivity service, with the said second antenna being a slot antenna and requiring very small area on the PCB.

Another aspect of the invention relates to the technique to obtain good isolation between the said first antenna and the said second antenna. According to the present invention, good isolation between the antennas included in the handset or handheld device can be obtained by appropriately choosing the placement and orientation on the PCB of each one of the antennas comprised in the handset or handheld device, and by acting on the PCB of the handset or handheld device to reduce the electromagnetic coupling between antennas.

Background of the invention

The current trend in the sector of mobile phone manufacturers, and more generally handheld device manufacturers, is to incorporate added value wireless services such as connectivity functionality and geolocalization (such as for example, but not limited to Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB) in more and more of their products.

In some cases, these handheld devices also operate in at least a frequency band used for mobile communication services, such as GSM (GSM850, GSM900, GSM1800, American GSM or PCS1900, GSM450), UMTS, WCDMA, or CDMA, apart from having the ability to operate in the frequency band corresponding to the wireless connectivity service.

Although it is possible to integrate all the operating bands of a particular handheld device in a single antenna, the trend in the handset manufacturing industry shows that it is preferred to have two separate antennas: A first antenna is used for the bands of the selected mobile communication services, and a second antenna is used to allow the device to operate at an additional communication service (such as for instance UMTS) or at the frequency bands of a wireless connectivity standard.

Using two separate antennas presents some advantages:

- It eases the design of each one of the antennas, as a single multiband antenna covering all the bands of operation of the handset would require a more complicated design.

- It also simplifies the radiofrequency (RF) front-end for each one of the two antennas. In the event of having a single antenna, the RF front-end to which the antenna is connected would have to include a diplexer capable of separating the mobile communication frequency bands from the wireless connectivity frequency bands.

- Moreover, it offers more flexibility in the design of the printed circuit board (PCB) that carries the electronic components and circuitry of the handset or handheld device. In many cases, a PCB designer will preferably lay out the module or chipset providing the wireless connectivity functionality, and the module or chipset for the mobile communication services in different parts of the PCB.

The said first antenna can typically be for instance and without limitation a monopole antenna, an inverted-F antenna (IFA), a patch antenna, or a planar inverted-F antenna (PIFA). Some known solutions for the said second antenna include antennas printed on the PCB of the device (such as for example, but not limited to, a printed IFA), or an antenna component, or chip antenna.

However, the integration in a handset of a second antenna dedicated to the wireless connectivity services is not trivial. As the space available on the PCB of the device is scarce, antenna solutions with small footprint are advantageous. Printed antennas typically are not small in size, since their dimensions are approximately a quarter of an operating wavelength of the antenna. Chip antennas may achieve some degree of miniaturization (for instance by loading the antenna with a material with high dielectric constant), however in many cases they exhibit poor matching levels, and limited bandwidth, efficiency or gain.

One additional problem that further complicates the integration of the wireless connectivity antenna in a handset or handheld device is the low isolation that is obtained between this antenna and the antenna used for mobile communications.

Interband isolation can be improved by separating the two antennas further apart, although this might not be practical in typical handsets due to their small size and limited positions that are available to integrate the wireless connectivity antenna. This is the case especially for more recent handset topologies like for example flip-type, or clamshell, phones and slider-type phones (as the one shown in Figure 1). As an alternative, a filter can be used to achieve the required level of isolation between antennas within the operating bands. However, this approach implies adding extra components on the PCB, thus using up more space on the PCB of the device, and resulting in an increase in cost of the handset.

A conventional handset that includes an antenna for mobile communications and an antenna for wireless connectivity is depicted in Figure 2. For this example, the handset has been selected to have a slider-type topology (see Figure 1). A slider-type handset comprises typically a first PCB (101) placed substantially above and parallel to a second PCB (102). The first PCB (101) has the ability to slide above

the second PCB (102), so that the handset can be in a closed position, as shown in Figure 1a or in an open position, as shown in Figure 1b. Generally, the first PCB (101) and the second PCB (102) are electrically connected, for example by means of a flexible conductive film.

For the purpose of the example, the handset comprises a first antenna (201) placed on the top part of the PCB (200) that operates at the frequency bands for mobile communications, and a second antenna (202) placed on the bottom right corner of the PCB (200) that operates at the frequency bands of the wireless connectivity services. For illustrative purposes, the second antenna (202) is a surface mount technology (SMT) component mounted on the PCB (200), although it could have been replaced by an antenna printed on the PCB (200).

Some typical electrical results for the handset of Figure 2 are shown without any limiting purpose in Figure 3. Figure 3a presents typical results of the input parameters of the antennas (i.e., return losses of each antenna, and isolation between antennas) when the slider-type phone is in the closed position, while Figure 3b presents the typical results of the antennas when the phone is in the open position. In this example, the first antenna (201) was designed to have a multiband behavior, with a first resonance around 900MHz to provide coverage for the GSM900 service, and a second resonance around 1900MHz to provide service to the GSM1800 and GSM1900 services. On the other hand the second antenna was designed to be tuned in the 2500MHz band. These frequency ranges have been selected just to illustrate the example, but the antennas could work in any frequency band included in the range from approximately 400MHz to approximately 12GHz, including any subinterval. The isolation between the first antenna (201) and the second antenna (202) is 20dB in the 900MHz band, 18dB in the 1900MHz band. Moreover, the isolation degrades to 17dB at the center of the resonance of the second antenna around 2600MHz.

Salto de página

Space Filling Curves

In some examples, at least one antenna of the antennas included in the handset or handheld device may be miniaturized by shaping at least a portion of the conducting trace, conducting wire or contour of a conducting sheet of the antenna (e.g., a part of the arms of a dipole, the perimeter of the patch of a patch antenna, the slot in a slot antenna, the loop perimeter in a loop antenna, or other portions of the antenna) as a space-filling curve (SFC).

A SFC is a curve that is large in terms of physical length but small in terms of the area in which the curve can be included. More precisely, for the purposes of this patent document, a SFC is defined as follows: a curve having at least five segments, or identifiable sections, that are connected in such a way that each segment forms an angle with any adjacent segments, such that no pair of adjacent segments defines a larger straight segment. In addition, a SFC does not intersect with itself at any point except possibly the initial and final point (that is, the whole curve can be arranged as a closed curve or loop, but none of the lesser parts of the curve form a closed curve or loop).

A space-filling curve can be fitted over a flat or curved surface, and due to the angles between segments, the physical length of the curve is larger than that of any straight line that can be fitted in the same area (surface) as the space-filling curve. Additionally, to shape the structure of a miniature antenna, the segments of the SFCs should be shorter than at least one fifth of the free-space operating wavelength, and possibly shorter than one tenth of the free-space operating wavelength. The space-filling curve should include at least five segments in order to provide some antenna size reduction, however a larger number of segments may be used. In general, the larger the number of segments and the narrower the angles between them, the smaller the size of the final antenna.

Salto de página

Box-Counting Curves

In other examples, at least one antenna of the antennas included in the handset or handheld device may be miniaturized by shaping at least a portion of the

conducting trace, conducting wire or contour of a conducting sheet of the antenna to have a selected box-counting dimension.

For a given geometry lying on a surface, the box-counting dimension is computed as follows. First, a grid with substantially squared identical cells boxes of size L1 is placed over the geometry, such that the grid completely covers the geometry, that is, no part of the curve is out of the grid. The number of boxes N1 that include at least a point of the geometry are then counted. Second, a grid with boxes of size L2 (L2 being smaller than L1) is also placed over the geometry, such that the grid completely covers the geometry, and the number of boxes N2 that include at least a point of the geometry are counted. The box-counting dimension D is then computed as:

$$D = -\frac{\log(N2) - \log(N1)}{\log(L2) - \log(L1)}$$

For the purposes of the antennas included in the handset or handheld device described herein, the box-counting dimension may be computed by placing the first and second grids inside a minimum rectangular area enclosing the conducting trace, conducting wire or contour of a conducting sheet of the antenna and applying the above algorithm. The first grid should be chosen such that the rectangular area is meshed in an array of at least 5 x 5 boxes or cells, and the second grid should be chosen such that L2 = 1/2 L and such that the second grid includes at least 10 x 10 boxes. The minimum rectangular area is an area in which there is not an entire row or column on the perimeter of the grid that does not contain any piece of the curve.

The desired box-counting dimension for the curve may be selected to achieve a desired amount of miniaturization. The box-counting dimension should be larger than 1.1 in order to achieve some antenna size reduction. If a larger degree of miniaturization is desired, then a larger box-counting dimension may be selected, such as a box-counting dimension ranging from 1.5 to 3. For the purposes of this patent document, curves in which at least a portion of the geometry of the curve

has a box-counting dimension larger than 1.1 are referred to as box-counting curves.

For very small antennas, for example antennas that fit within a rectangle having maximum size equal to one-twentieth the longest free-space operating wavelength of the antenna, the box-counting dimension may be computed using a finer grid. In such a case, the first grid may include a mesh of 10 x 10 equal cells, and the second grid may include a mesh of 20 x 20 equal cells. The box-counting dimension (D) may then be calculated using the above equation.

In general, for a given resonant frequency of the antenna, the larger the box-counting dimension, the higher the degree of miniaturization that will be achieved by the antenna. One way to enhance the miniaturization capabilities of the antenna is to arrange the several segments of the curve of the antenna pattern in such a way that the curve intersects at least one point of at least 14 boxes of the first grid with 5 x 5 boxes or cells enclosing the curve. If a higher degree of miniaturization is desired, then the curve may be arranged to cross at least one of the boxes twice within the 5 x 5 grid, that is, the curve may include two non-adjacent portions inside at least one of the cells or boxes of the grid.

Figure 17 illustrates an example of how the box-counting dimension of a curve (1700) is calculated. The example curve (1700) is placed under a 5 x 5 grid (1701) and under a 10 x 10 grid (1702). As illustrated, the curve (1700) touches N1=25 boxes in the 5 x 5 grid (1701) and touches N2=78 boxes in the 10 x 10 grid (1702). In this case, the size of the boxes in the 5 x 5 grid (1701) is twice the size of the boxes in the 10 x 10 grid (1702). By applying the above equation, the box-counting dimension of the example curve (1700) may be calculated as D=1.6415. In addition, further miniaturization is achieved in this example because the curve (1700) crosses more than 14 of the 25 boxes in grid (1701), and also crosses at least one box twice, that is, at least one box contains two non-adjacent segments of the curve. More specifically, the curve (1700) in the illustrated example crosses twice in 13 boxes out of the 25 boxes.

Grid Dimension Curves

In further examples, at least one antenna of the antennas included in the handset or handheld device may be miniaturized by shaping at least a portion of the conducting trace, conducting wire or contour of a conducting sheet of the antenna to include a grid dimension curve.

For a given geometry lying on a planar or curved surface, the grid dimension of curve may be calculated as follows. First, a grid with substantially identical cells of size L1 is placed over the geometry of the curve, such that the grid completely covers the geometry, and the number of cells N1 that include at least a point of the geometry are counted. Second, a grid with cells of size L2 (L2 being smaller than L1) is also placed over the geometry, such that the grid completely covers the geometry, and the number of cells N2 that include at least a point of the geometry are counted again. The grid dimension D is then computed as:

$$D = -\frac{\log(N2) - \log(N1)}{\log(L2) - \log(L1)}$$

For the purposes of the antennas included in the handset or handheld device described herein, the grid dimension may be calculated by placing the first and second grids inside the minimum rectangular area enclosing the curve of the antenna and applying the above algorithm. The minimum rectangular area is an area in which there is not an entire row or column on the perimeter of the grid that does not contain any piece of the curve.

The first grid may, for example, be chosen such that the rectangular area is meshed in an array of at least 25 substantially equal cells. The second grid may, for example, be chosen such that each cell of the first grid is divided in 4 equal cells, such that the size of the new cells is L2 = ½ L1, and the second grid includes at least 100 cells.

The desired grid dimension for the curve may be selected to achieve a desired amount of miniaturization. The grid dimension should be larger than 1 in order to

achieve some antenna size reduction. If a larger degree of miniaturization is desired, then a larger grid dimension may be selected, such as a grid dimension ranging from 1.5 - 3 (e.g., in case of volumetric structures). In some examples, a curve having a grid dimension of about 2 may be desired. For the purposes of this patent document, a curve having a grid dimension larger than 1 is referred to as a grid dimension curve.

In general, for a given resonant frequency of the antenna, the larger the grid dimension the higher the degree of miniaturization that will be achieved by the antenna. One example way of enhancing the miniaturization capabilities of the antenna is to arrange the several segments of the curve of the antenna pattern in such a way that the curve intersects at least one point of at least 50% of the cells of the first grid with at least 25 cells enclosing the curve. In another example, a high degree of miniaturization may be achieved by arranging the antenna such that the curve crosses at least one of the cells twice within the 25-cell grid, that is, the curve includes two non-adjacent portions inside at least one of the cells or cells of the grid.

Multilevel Structures

In some examples, at least a portion of the conducting trace, conducting wire or conducting sheet of at least one antenna of the antennas included in the handset or handheld device may be coupled, either through direct contact or electromagnetic coupling, to a conducting surface, such as a conducting polygonal or multilevel surface. A multilevel structure is formed by gathering several geometrical elements, such as polygons or polyhedrons of the same type (e.g., triangles, parallelepipeds, pentagons, hexagons, circles or ellipses as special limiting cases of a polygon with a large number of sides, as well as tetrahedral, hexahedra, prisms, dodecahedra, etc.) and coupling electromagnetically at least some of such geometrical elements to one or more other elements, whether by proximity or by direct contact between elements. The majority of the component elements of a multilevel have more than 50% of their perimeter (for polygon and surface like elements) not in contact with any of the

other elements of the structure. Thus, the component elements of a multilevel structure may typically be identified and distinguished, presenting at least two levels of detail: that of the overall structure and that of the polygon or polyhedron elements that form it.

Additionally, several multilevel structures may be grouped and coupled electromagnetically to each other to form higher-level structures. In a single multilevel structure, all of the component elements are polygons with the same number of sides or are polyhedrons with the same number of faces. However, this characteristic is not present when several multilevel structures of different natures are grouped and electromagnetically coupled to form meta-structures of a higher level.

A multilevel antenna includes at least two levels of detail in the body of the antenna: that of the overall structure and that of the majority of the elements (polygons or polyhedrons) which make it up. This may be achieved by ensuring that the area of contact or intersection (if it exists) between the majority of the elements forming the antenna is only a fraction of the perimeter or surrounding area of said polygons or polyhedrons.

One example property of multilevel antennae is that the radioelectric behavior of the antenna can be similar in more than one frequency band. Antenna input parameters (e.g., impedance and radiation pattern) remain similar for several frequency bands (i.e., the antenna has the same level of adaptation or standing wave relationship in each different band), and often the antenna presents almost identical radiation diagrams at different frequencies. The number of frequency bands is proportional to the number of scales or sizes of the polygonal elements or similar sets in which they are grouped contained in the geometry of the main radiating element.

In addition to their multiband behavior, multilevel structure antennae may have a smaller than usual size as compared to other antennae of a simpler structure (such as those consisting of a single polygon or polyhedron). Additionally, the edge-rich and discontinuity-rich structure of a multilevel antenna may enhance the

radiation process, relatively increasing the radiation resistance of the antenna and reducing the quality factor Q (i.e., increasing its bandwidth).

A multilevel antenna structure may be used in many antenna configurations, such as dipoles, monopoles, patch or microstrip antennae, coplanar antennae, reflector antennae, wound antennae, antenna arrays, or other antenna configurations. In addition, multilevel antenna structures may be formed using many manufacturing techniques, such as printing on a dielectric substrate by photolithography (printed circuit technique); dieing on metal plate, repulsion on dielectric, or others.

Summary of the invention

The present invention discloses a handset or handheld device (such as for instance a mobile phone, a smartphone, a PDA, a MP3 player, a headset, a USB dongle, a laptop, a PCMCIA or Cardbus 32 card), which comprises a first antenna for mobile communications (hereinafter also referred to as the mobile antenna), and a second antenna for at least a mobile communication service or a wireless connectivity service (hereinafter also referred to as the wireless connectivity antenna), wherein the said second antenna is a slot antenna and requires very small area on the PCB.

According to the present invention, good isolation between antennas can be obtained by appropriately choosing the orientation on the PCB, and by selecting the antenna type (i.e., whether a given antenna substantially behaves as an electric current source, or as a magnetic current source) for each one of the antennas comprised in the handset or handheld device.

In some cases, wherein the first antenna substantially behaves as an electric current source (such as for instance, but not limited to, a monopole antenna) and the second antenna substantially behaves as a magnetic current source (for instance, but not limited to, a slot antenna), good isolation between the said first antenna and the said second antenna can be obtained when the electric currents excited on at least a portion of the PCB by the radiating mode of the

said first antenna are substantially parallel to the equivalent magnetic currents excited on at least a portion of the extension of the said second antenna.

In other cases, wherein the first and second antenna behave as magnetic current sources, good isolation between the said first antenna and second antenna is achieved when the magnetic currents excited on at least a portion of the extension of the first antenna are substantially orthogonal to the magnetic currents excited on at least a portion of the extension of the second antenna.

Another aspect of the invention relates to the technique to further improve the isolation between a mobile antenna and a wireless connectivity antenna in a handset or handheld device, by acting on the geometry of the mobile antenna to eliminate any resonance modes that might fall within any of the operating bands of the wireless connectivity antenna.

List of figures

Further characteristics and advantages of the invention will become apparent in view of the detailed description which follows of some preferred embodiments of the invention given for purposes of illustration only and in no way meant as a definition of the limits of the invention, made with reference to the accompanying drawings, in which:

Fig. 1 – Example of a slider-type handset carrying an antenna for mobile communications (100) and comprising a top PCB (101) (with dimensions 78mm x 40mm for the purpose of the example) and a bottom PCB (102) (with dimensions 70mm x 35mm, in this example): **(a)** General view of the PCBs of the handset in the closed position; and **(b)** general view of the PCBs of the handset in the open position.

Fig. 2 – Top view of an example of a handset comprising a first antenna for mobile communications placed on the top portion of the PCB of the handset and a

second antenna for wireless connectivity services placed on the bottom right corner of the PCB.

Fig. 3 – Typical electrical performance of the antennas of the handset shown in Fig. 2: **(a)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and **(b)** return loss of each antenna and isolation between antennas when the handset is in open position.

Fig. 4 – Top view of an example of a handset according to the present invention including a first antenna for mobile communications placed on the top portion of the PCB of the handset and a second antenna for wireless connectivity services placed on the bottom right corner of the PCB, wherein the second antenna is a slot antenna: **(a)** General view of the PCB of the handset carrying the two antennas; and **(b)** detailed view of the region that contains the slot antenna.

Fig. 5 – Typical electrical performance of the antennas of the handset shown in Fig. 4: **(a)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and **(b)** return loss of each antenna and isolation between antennas when the handset is in open position.

Fig. 6 – Typical radiation and antenna efficiency of the slot antenna for wireless connectivity integrated in the handset of Fig. 4.

Fig. 7 – Top view of some implementations of the handset comprising a mobile antenna (white rectangle with black diagonal lines) and a slot antenna (black line) on the PCB (grey rectangle) for wireless connectivity services.

Fig. 8 – Typical electrical performance of the antennas of the handset shown in Fig. 7b: **(a)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and **(b)** return loss of each antenna and isolation between antennas when the handset is in open position.

Fig. 9 – **(a)** Detailed view of an example of a handset comprising a first antenna for mobile communications and a second antenna for wireless connectivity

services. The geometry of the antenna for mobile communications can be tailored according to the teachings of the present invention to enhance the isolation with the antenna for wireless connectivity services by **(b)** modifying the dimensions of an arm of the mobile antenna; or **(c)** folding an arm of the mobile antenna.

Fig. 10 – Comparison of typical levels of isolation between the mobile antenna and the wireless connectivity antenna that can be obtained before and after modifying the mobile antenna as depicted in Fig. 9b.

Fig. 11 – Detailed view of an antenna for mobile communications whose geometry has been modified according to the teachings of the present invention to enhance the isolation with the antenna for wireless connectivity services by increasing the length of a slot defined in the structure of the mobile antenna by means of: **(a)** shaping the slot as a meander-like curve; or **(b)** adding a conductive stripe inside the aperture of the slot.

Fig. 12 – Comparison of typical levels of isolation between the mobile antenna and the wireless connectivity antenna that can be obtained before and after modifying the mobile antenna as depicted in Fig. 11b.

Fig. 13 – Detailed view of the top portion of the PCB of a handset showing different embodiments according to the present invention to enhance the isolation between an antenna for mobile communications and an antenna for wireless connectivity services by: **(a)** introducing a slot on the PCB; or **(b)** placing a conductive stripe above the PCB that is shorted on one end to the PCB.

Fig. 14 – Comparison of typical levels of isolation between the mobile antenna and the wireless connectivity antenna that can be obtained before and after modifying the PCB of the handset as depicted in Fig. 13b.

Fig. 15 – Embodiment of a handset according to the present invention including a mobile antenna, a wireless connectivity antenna, and parasitic element to enhance the isolation between antennas: **(a)** General view of the PCB of the handset; and **(b)** detailed view of the top portion of the PCB of the handset

showing the shape of the parasitic element. (For the sake of clarity, the parasitic element appears to be in Fig. 15b above the mobile antenna, although in reality it is placed below the mobile antenna but above the plane of the PCB of the handset.)

Fig. 16 – Comparison of typical levels of isolation between the mobile antenna and the wireless connectivity antenna that can be obtained before and after introducing a parasitic element, like the one shown in Fig. 15, in the handset.

Fig. 17 – Example of a box counting curve located in a first grid of 5x5 boxes and in a second grid of 10x10 boxes.

Fig. 18 – Example of a grid dimension curve.

Fig. 19 – Example of a grid dimension curve located in a first grid.

Fig. 20 – Example of a grid dimension curve located in a second grid.

Fig. 21 – Example of a grid dimension curve located in a third grid.

Description of the preferred embodiments

In some preferred embodiments of the handset or handheld device of the present invention, the said handset or handheld device comprises a first antenna used for at least a mobile communication service, and a second antenna used for at least a wireless connectivity service, wherein the second antenna is a slot antenna (Figure 4). In the example of Figure 4, and without being a limitation of the invention, the slot (402) has been created on the ground plane of the PCB (400) on its right hand side and near the bottom. The shape of the slot (402), and the length and widths of each one of the segments that form the said slot (402), can be selected to meet the requirements of resonance frequency, electrical performance, and maximum PCB area constraint, of a given handset or handheld device.

In the example of Figure 4, the slot (402) intersects the perimeter of the ground plane of the PCB (400) at one point (406). In other words, the slot (402) is not completely surrounded by conducting materials. In some preferred cases, the unfolded length of the slot (402) will be approximately a quarter of an operating wavelength of the slot antenna. In some other cases, the unfolded length of the slot (402) will be approximately three times, or approximately five times, or approximately another odd integer number of times, the length of one quarter of an operating wavelength of the slot antenna.

In other embodiments, the slot might intersect the perimeter of the ground plane of the PCB on which is placed at least at one point, such as for example at two points. In yet some other embodiments, the slot might not intersect the perimeter of the ground plane of the PCB on which is placed. That is, the slot is in these cases completely surrounded by conducting materials. In some embodiments, it might be advantageous that the unfolded length of the slot be approximately twice, or approximately four times, or approximately another even integer number of times, the length of one quarter of an operating wavelength of the slot antenna.

In order to minimize the coupling between the first antenna (401) and the second antenna (402) (i.e., maximize the isolation), the design of the slot (402) and its orientation with respect to the PCB (400) is selected such that the slot (402) is substantially parallel to the direction of the currents excited on the PCB (400) by a resonating mode of the first antenna (401), at least on a portion of the PCB (400). In some cases, it is advantageous to design the slot (402) such that it is substantially parallel to the longer side of the PCB (400), because the currents excited on said PCB (400) by the resonating mode of the first antenna (401) tend to be substantially parallel to said longer side of the PCB (400). In the context of this application, two directions are considered to be substantially parallel if they form an angle of less than, or equal to, approximately 30 degrees. Also in the context of this application, the direction of a slot is defined by the direction of the longest side of the rectangular area in which said slot is inscribed.

In some other cases the first antenna may include a slot that radiates at a particular resonance frequency, so that the said first antenna behaves substantially as a magnetic current source for that resonance frequency. In these embodiments it will be advantageous to align the said slot of the first antenna along a first direction and the slot of the second antenna along a second direction, being said first direction substantially orthogonal to said second direction. In the context of this application, two directions are considered to be substantially orthogonal if they form an angle in the range from approximately 60 degrees to approximately 120 degrees.

The shape of the slot (402) can comprise straight and curved segments, not necessarily all segments being of the same length (see examples in Figure 7). In the same way, the separation between the conductive edges of each segment of the slot (402) does not have to be the same for all segments, nor constant for any given segment (i.e., any segment of the slot (402) can be tapered).

In some examples, the slot (402) might have one, two, three, or more bends. In general, as the number of bends in the slot (402) increases, the shape of the slot (402) becomes more and more convoluted, leading to a higher degree of miniaturization of the resulting slot antenna.

In some cases, the slot antenna will be advantageously excited by applying a voltage difference between the opposite conductive edges of the slot (402) at a particular point (408) along the geometry of the slot (hereinafter referred to as the feeding point). In some embodiments, the feeding point (408) will be closer to the closed end of the slot (407) than to the open end of the slot (406). In certain examples, the distance between the feeding point (408) and the closed end of the slot (407) will be less than, or equal to, 0.2%, 0.4%, 0.8%, 1.2% 1.6%, 2.5%, 3.3%, 4% or 8% of a free-space operating wavelength of the slot antenna.

In some examples, it will be advantageous to have the slot antenna (402) inscribed in a rectangular area (403) of width (405) smaller than 1/50 of the free-space operating wavelength of the slot antenna (402), and length (404) smaller

than 1/4 of the free-space operating wavelength. Being more general, in some embodiments the said width (405) divided by the free-space operating wavelength of the slot antenna will be smaller than, or equal to, at least one of the following fractions: 1/10, 1/30, 1/50, 1/60, 1/70, or 1/80. In the same way, for some embodiments the said length (404) divided by the free-space operating wavelength of the slot antenna will be smaller than, or equal to, at least one of the following fractions: 1/2, 1/3, or 1/4. In some other instances, it will be advantageous that the sum of the length (404) and the width (405) of the rectangular area (403) in which the slot is inscribed be smaller than 1/2 of the free-space operating wavelength, or even smaller than 1/4 of the free-space operating wavelength. Furthermore, it will be advantageous in some cases that the separation between the two edges of the slot (402) be within a range from approximately the 0.08% of the free-space operating wavelength to approximately the 8% of the free-space operating wavelength, including any subinterval of said range.

The slot antenna in some examples will be implemented as a slot printed or etched on the ground plane of the PCB, while in other cases the slot will be contained in a surface mount technology (SMT) type component mounted on the PCB of the handset or handheld device. When the slot is contained in a SMT type component, said component will comprise a conducting surface on which the slot is created. The SMT type component will provide at least one contact terminal accessible from the exterior of said SMT component to electrically connect said conducting surface with the ground plane of the PCB. In some embodiments, this contact terminal can take the form of a pad, or a pin, or a solder ball. It will be advantageous in some cases to define on the PCB a region of clearance of ground plane on the orthogonal projection of the component on the PCB on which it is mounted. In other cases, there will be ground plane on a portion of the orthogonal projection of the SMT component on the PCB, but not under the orthogonal projection of the slot on said PCB.

Figure 5 presents, without any limiting purpose, an example of electrical results for the handset of Figure 4 according to the present invention. Figure 5a presents typical values of the input parameters of the antennas (i.e., return losses of each

antenna, and isolation between antennas) when the slider-type phone is in the closed position, while Figure 5b presents the typical results of the antennas when the phone is in the open position. In this example, the first antenna (401) was designed to have a multiband behavior, with a first resonance around 900MHz to provide coverage for the GSM900 service, and a second resonance around 1900MHz to provide service to the GSM1800 and GSM1900 standards. On the other hand the second antenna was designed to be tuned in the 2500MHz band. The isolation between the first antenna (401) and the second antenna (402) exceeds 30dB in the 900MHz band, is better than 23dB in the 1900MHz band, and better than 21dB in the 2500MHz band. The level of isolation attained between the antennas of the example shown in Figure 4 is better than the results obtained for the example of a conventional prior-art arrangement in Figure 2. A typical radiation performance of the slot antenna (402) is shown without any limiting purpose in Figure 6. The slot antenna (402) has a level of radiation efficiency in excess of 60% in its band of operation both in the open and closed positions of the handset.

In some embodiments, the use of a slot antenna as the wireless connectivity antenna for a handset or handheld device according to the present invention can be advantageous because:

- It has low profile and uses very little space of the PCB.
- It is less sensitive to the size, shape or form factor of the PCB on which is printed, etched, or mounted as a SMT component. This can be particularly interesting for flip-type and slider-type handsets in which the antenna needs to stay within functional specifications for the PCB configuration of the handset in both the open and closed positions.
- It can be polarized along a direction that is substantially orthogonal to the polarization of the mobile antenna.

Figure 7 presents, without any limiting purpose, some embodiments for the present invention of a handset or handheld device comprising a slot antenna. Generally, it will be preferable to keep the separation between the mobile antenna (701) and the wireless connectivity antenna (702) as large as possible in order to maximize the isolation between the antennas. For example, isolation between the

antennas on the PCB for the case of Figure 7c is expected to be better than for the case of Figure 7a, as the separation between the antennas is larger. However, in certain embodiments it may not be possible to place the mobile antenna (701) and the wireless connectivity antenna (702) further apart. In these cases it will be necessary the use of additional techniques to improve further the isolation between the mobile antenna and the wireless connectivity antenna by acting either on the geometry of the mobile antenna, or on the PCB of the handset or the handheld device, or on both.

The electrical performance of the antennas in the embodiment of Figure 7b is presented without any limiting purpose in Figure 8. As it can be observed, the return loss of each antenna is practically the same as the one already presented in Figure 5. However, there is a degradation in the isolation between the mobile antenna (701) and the wireless connectivity antenna (702), predominantly around 2400MHz, linked to the smaller separation between antennas.

Another aspect of the invention relates to techniques to enhance the isolation between the mobile antenna and the wireless connectivity antenna. Some of these techniques comprise the steps of shaping the geometry of the mobile antenna to eliminate higher order resonant modes or spurious modes that may fall within an operating band of the wireless connectivity antenna, giving rise to strong coupling of the mobile antenna with the wireless connectivity antenna.

In some embodiments, the mobile antenna can comprise features (such as for instance a slot, or a stripe of metal) with an electrical length close to approximately an integer multiple of a quarter of an operating wavelength of the wireless connectivity antenna. For example, in the embodiment of Figure 9a the mobile antenna (901) comprises a slot (903) that has a length of approximately a quarter of the wavelength at 2600MHz, corresponding to an operating band of the wireless connectivity antenna. For the purposes of this example and the following ones, a wireless connectivity antenna (902) has been placed near the top left corner of the PCB (900) underneath the mobile antenna (901). As commented previously, this is not particularly an advantageous position for the wireless connectivity antenna (902), as the little distance with respect to the mobile

antenna (901) will translate into poor isolation. As it can be seen in Figure 10, a typical level of isolation between antennas at 2600MHz is approximately 8dB. However, this antenna arrangement will help to illustrate the improvement in isolation between antennas that can be achieved by following the teachings disclosed in this patent application.

In order to increase the isolation between antennas, the length of the slot (903) can be shortened to force the associated resonance frequency to move towards higher frequencies, away from the wireless connectivity band. In the embodiment Figure 9b, the conducting arm of the mobile antenna (934) has been shortened by some amount with respect to the original arm (904), so that the resulting slot (933) is shorter or substantially shorter than a quarter of the resonant wavelength of the wireless antenna and therefore resonates at a higher frequency.

The resonance frequencies of the mobile antenna (931) might shift in frequency as a consequence of the shortening of the conducting arm (934). The operating bands of the mobile antenna (931) can be readily retuned using for example a matching network at the feeding point of the antenna. As an alternative, it can be preferred to lengthen the arm (934) to retune the operating bands of the mobile antenna (931), while keeping the length of slot (933) constant. In that sense, the embodiment in Figure 9c shows a mobile antenna (961) in which the conducting arm (964) has been folded as a U shape, while ensuring that the length of the slot (963) is shorter than that of the slot (903). In this case, the end of the conducting arm (964) does not coincide with the open end of the slot (963), as it was the case of embodiment in Fig. 9a, where the tip of arm (904) defined the open end of the slot (903). Figure 10 presents without any limiting purpose typical antenna isolation that can be obtained with a modified mobile antenna like the one in Figure 9c, and compares it with the isolation obtained with the original mobile antenna (Figure 9a).

In some cases in order to achieve a good improvement in isolation between antennas, the length of a slot, or a conducting stripe, or more generally a geometric feature of the mobile antenna which has an associated resonance within a band of the wireless connectivity antenna, will be modified (i.e., shortened

or enlarged) about a 12%, or about 20%, or even about a 30%, of the original length of the said slot, or said conducting stripe, or said geometrical feature of the mobile antenna.

In some other embodiments it can be advantageous to increase a dimension of a feature of the mobile antenna with an associated resonance at a frequency within an operating band of the wireless connectivity antenna. Figure 11 discloses two embodiments of a handset comprising a mobile antenna and a wireless connectivity antenna that use this technique to improve the antenna isolation. In the case of Figure 11a, the slot (903) in the original mobile antenna (901) has been replaced by a meander-like slot (1103) to make it electrically longer and shift the resonance associated to this slot (1103) well below the operating band of the wireless antenna (1102). In some embodiments of the present invention at least a portion of the slot (1103) will be preferably shaped as a space-filling curve, a box-counting curve, a grid-dimension curve, or a fractal based curve, to achieve maximum size compression.

The embodiment in Figure 11b is advantageous in increasing the electrical length of the slot (903) of the original mobile antenna (901). In this case, the mobile antenna (1151) comprises a metal stripe (1154) that is placed between the edges of the slot (903) and shorted at one end to the main body of the mobile antenna (1151) in the region (1155). In certain cases, the metal stripe (1154) will be long enough to cover substantially the slot (903), while in other cases the metal stripe (1154) will be shorter and be placed in just a portion of the slot (903). The resulting U-shaped slot will have an associated resonance frequency lower than that of the original slot (903). Figure 12 presents without any limiting purpose typical antenna isolation that can be obtained with a modified mobile antenna like the one in Figure 11b, and compares it with the isolation obtained with the original mobile antenna (Figure 9a). In some embodiments, such a technique improves the isolation in 4dB or more.

Some other techniques to enhance the isolation between the mobile antenna and the wireless connectivity antenna in a handset or handheld device according to the present invention comprise the steps of modifying the geometry of the PCB of

the said handset or handheld device to introduce on the said PCB a feature able to increase the isolation between antennas in a particular frequency band.

Figure 13a presents an embodiment of a handset comprising a mobile antenna (1301), a wireless connectivity antenna (1302) and a PCB (1300), wherein a slot (1304) has been created in a ground plane of the said PCB (1300). The slot (1304) features an open end. That is, the slot (1304) intersects the perimeter of the conducting pattern of the PCB (1300) in at least one point. In other words the slot (1304) is not completely surrounded by conducting materials. In this example, the unfolded length of the slot (1304) has been selected to be approximately a quarter of the wavelength at the frequency for which the isolation between antennas needs to be enhanced. More generally, the length of the slot (1304) can be adjusted to be approximately an odd integer multiple of a quarter of the wavelength at the frequency for which a higher level of isolation is needed.

A purpose of the slot (1304) is to present a high impedance path to the currents flowing on the perimeter of the ground plane of the PCB (1300) on which the slot (1304) is placed. Therefore, it will be preferred in certain embodiments, in order to increase the isolation, to place the slot (1304) at a point along the perimeter of the ground plane of the PCB (1300) in which the currents flowing from the wireless connectivity antenna (1302) towards the mobile antenna (1301) along the perimeter of the ground plane of the PCB (1300) are strong. In other embodiments, a purpose of shaping the ground plane with for instance one or more slots is to alter the phase and amplitude of the coupling and to generate multiple signal coupling paths such those multiple signals cancel each other.

Figure 13b discloses another embodiment of a handset comprising a mobile antenna (1301), a wireless connectivity antenna (1302) and a PCB (1350), wherein a conductive stripe (1354) has been placed above, and substantially parallel to, the ground plane of the said PCB (1350) and shorted at one end to the said PCB (1350). In the example of the figure, the unfolded length of the conducting stripe (1354) has been selected to be approximately a quarter of the wavelength at the frequency for which the isolation between antennas needs to be enhanced. Being more general, the length of the conducting stripe (1354) can be

adjusted to be approximately an odd integer multiple of a quarter of the wavelength at the frequency for which a higher level of isolation is needed.

Similarly to the slot (1304) in Figure 13a, a purpose of the conducting stripe (1354) is to present a high impedance path to the currents flowing on the ground plane of the PCB (1350) from the wireless connectivity antenna (1302) towards the mobile antenna (1301). Therefore, it will be advantageous in some cases, to place the shorted end of the conducting stripe (1354) at least a distance of approximately a quarter of the wavelength at the frequency for which a higher level of isolation is needed on the path that the currents flowing from the wireless connectivity antenna (1302) towards the mobile antenna (1301) follow on the ground plane of the PCB (1350).

Figure 14 presents without any limiting purpose typical antenna isolation that can be obtained with using a handset with a modified PCB as the one disclosed in Figure 13b. Compared with the isolation curve obtained in the original handset (Figure 9a), the presence of the shorted conducting stripe (1354) introduces a deep notch in the isolation in the region between 2600MHz and 2800MHz where the original handset had a poor isolation.

In other embodiments, the ground plane of the PCB of the handset or handheld device can have two or more slots, like the slot (1304) in Figure 13a, or two or more conducting stripes shorted to the ground plane of the PCB, like the conducting stripe (1354) in Figure 13b. By adjusting the number and length of the slots or the conducting stripes, the frequency behavior of the isolation between antennas can be tailored. In general, for a wide-band behavior, the length of the slots or the conducting stripes will be substantially similar. For a multiband response with no overlapping between frequency bands, the length of each slot or each conducting stripe is associated mainly with the center frequency of a particular band at which the isolation between antennas needs to be increased. In yet other embodiments, a single slot (or a single conducting stripe) with multiple branches can be used to obtain an improvement in the isolation with a wideband or multiband behavior.

In yet other embodiments, the handset or handheld device comprises a mobile antenna (1501), a wireless connectivity antenna (1502), and a conducting stripe (1504) placed in the vicinity of the mobile antenna (1501) and the wireless connectivity antenna (1502), but differently from what is disclosed in Figure 13b, the said conducting stripe (also referred to as parasitic element) is not connected to the ground plane of the PCB (1500). In the example of the Figure 15, the unfolded length of the conducting stripe (1504) has been selected to be approximately a half of the wavelength at the frequency for which the isolation between antennas needs to be enhanced. The resonance introduced by the said conducting stripe (1504) enhances the curve of isolation between antennas (see Figure 16, which is provided for the purposes of illustration only and in no way meant as a definition of the limits of the invention), improving substantially the isolation in the desired band (the 2600MHz – 2800MHz region in this particular example).

In some embodiments of the present invention (see for example Figures 13 and 15) at least a portion of the slot (1304), or a portion of the conducting stripe (1354) or (1504) will be preferably shaped as a space-filling curve, a box-counting curve, a grid-dimension curve, or a fractal based curve, to achieve maximum size compression.

A skilled-in-the-art person will recognize that the techniques disclosed in this patent application can be advantageously used to enhance the isolation between an antenna for mobile communications and an antenna for wireless connectivity services not only when the latter is a slot antenna but also for other types of antenna topology such as for instance, but not limited to, a monopole antenna, an IFA, a patch antenna or a PIFA

Generally, the present invention can facilitate the integration of the antennas inside several kinds of handsets or handheld devices so that the antennas can be arranged in a way that it is compatible with high density of components on the PCB of the device. For miniaturization purposes, at least a portion of the curve defining the conducting trace, conducting wire or contour of the conducting sheet of at least one antenna of the handset or handheld device will advantageously be

a space-filling curve, a box-counting curve, a grid-dimension curve, or a fractal based curve. The conducting trace, conducting wire or contour of the conducting sheet of said at least one antenna might take the form of a single curve, or might branch-out in two or more curves, which at the same time in some embodiments will be also of the space-filling, box-counting, grid-dimension, or fractal kinds. Additionally, in some embodiments a part of the curve will be coupled either through direct contact or electromagnetic coupling to a conducting polygonal or multilevel surface.

The teachings disclosed in the present patent application facilitate the adoption of the wireless functionality in handsets and other handheld devices. Handset and handheld device manufactures will benefit from the commercialization of such products with value-added features and that enjoy of stronger customer preference. In a platform like the one of a handset for mobile communications in which the efficient use of small-sized PCBs is paramount, the integration of a wireless connectivity antenna according to the present invention offers the benefit of small area overheads (i.e., smaller overall size of the handheld device), which translates into lower cost. Moreover, the enhanced isolation between antennas attainable using the techniques and teachings of the present invention provide handset and handheld device manufacturers with more flexibility when designing the layout of the PCB of the devices and the placement of the antennas and neighboring electronics on the PCB of the devices, reducing the costs of integration of the antenna, simplifying the new product development cycle, and accelerating the time to market of their new products.

In some preferred embodiments the handset or handheld device is operating at one, two, three or more of the following communication and connectivity services: GSM (GSM850, GSM900, GSM1800, American GSM or PCS1900, GSM450), UMTS, WCDMA, CDMA, Bluetooth™, IEEE802.11ba, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DMB, DVB-H.

CLAIMS

1. – A handheld device comprising:

- a first antenna operating in at least a first frequency band,
- a second antenna operating in at least a second frequency band,

wherein the said second frequency band is different from the said first frequency band; and wherein the said second antenna comprises a slot antenna.

2. – A handheld device comprising:

- a first antenna operating in at least a first frequency band,
- a second antenna operating in at least a second frequency band,
- a printed circuit board including a ground plane,

wherein the said second frequency band is different from the said first frequency band;

wherein the said first antenna is selected from the group consisting essentially of monopole antenna, IFA, patch antenna, and PIFA;

wherein the said second antenna comprises a slot antenna, wherein the said slot antenna is included in the ground plane of the said printed circuit board,

wherein the longest straight segment of the slot is substantially parallel to the longest edge of the said printed circuit board, wherein one open end of the slot is in contact with one edge of the said printed circuit board;

wherein the width of the rectangular area in which the said slot antenna is inscribed, divided by a free-space operating wavelength of the said slot antenna is smaller than, or equal to, at least one of the following fractions: 1/10, 1/30, 1/50, 1/60, 1/70, or 1/80;

wherein the length of the rectangular area in which the said slot antenna is inscribed, divided by a free-space operating wavelength of the said slot antenna is smaller than, or equal to, at least one of the following fractions: 1/2, 1/3, or 1/4;

wherein the said handheld device is a mobile handset, operating in at least one of the following mobile communication and wireless connectivity services: GSM (GSM850, GSM900, GSM1800, American GSM or PCS1900, GSM450), UMTS, WCDMA, CDMA, Bluetooth™, IEEE802.11ba, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DMB.

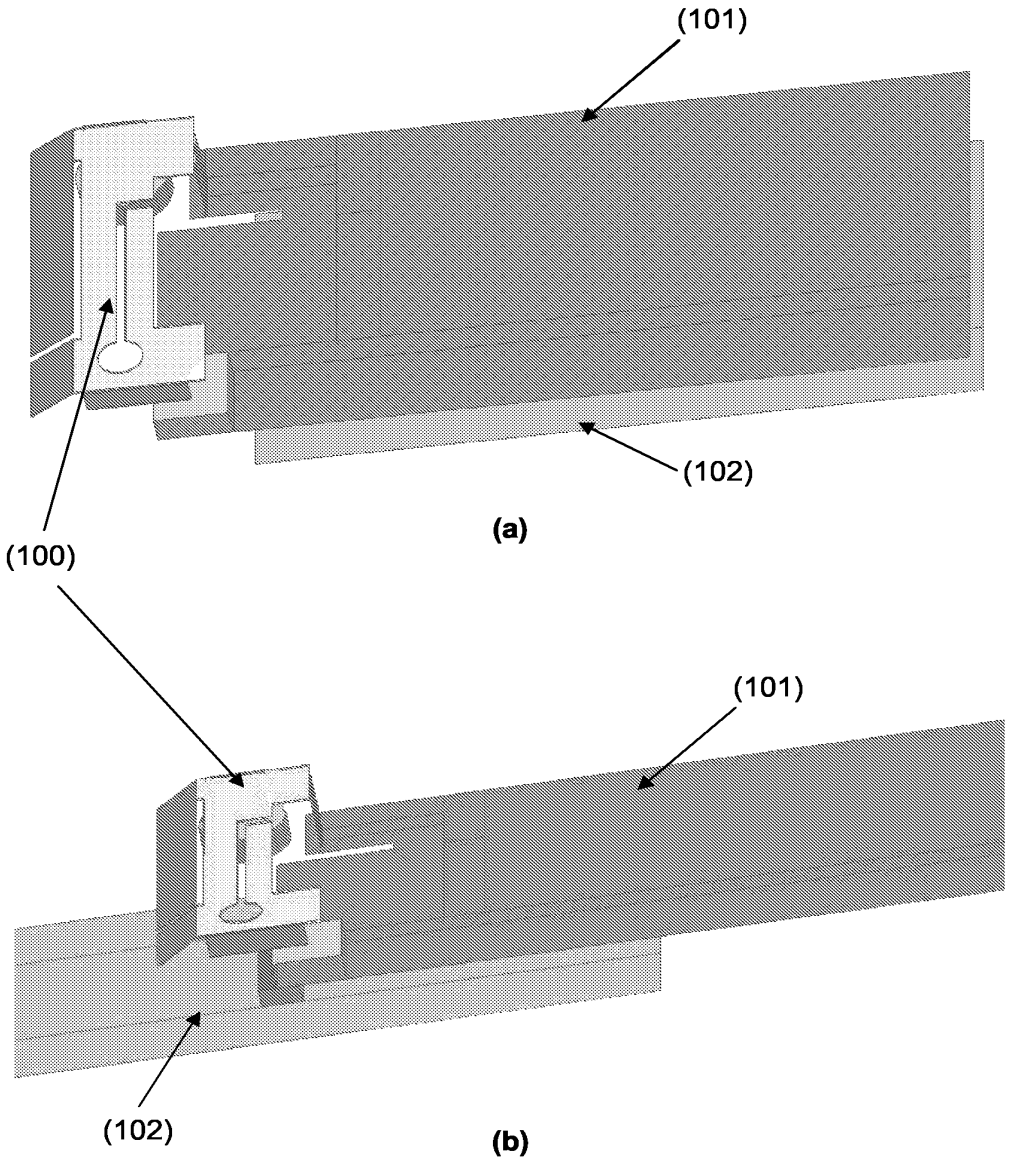


Fig. 1 (PRIOR ART)

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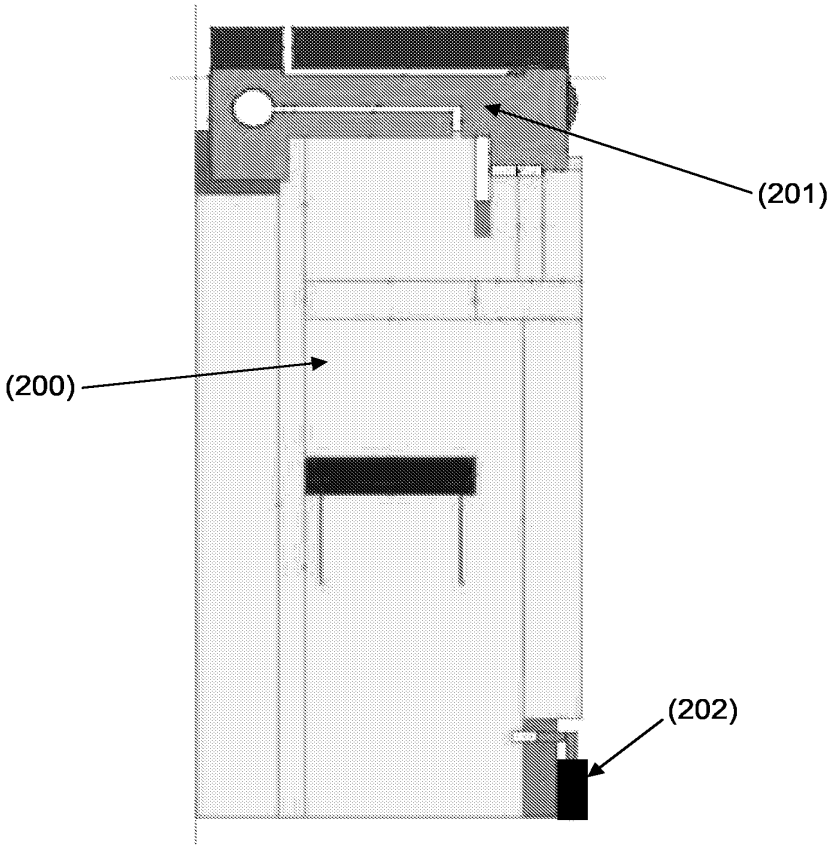
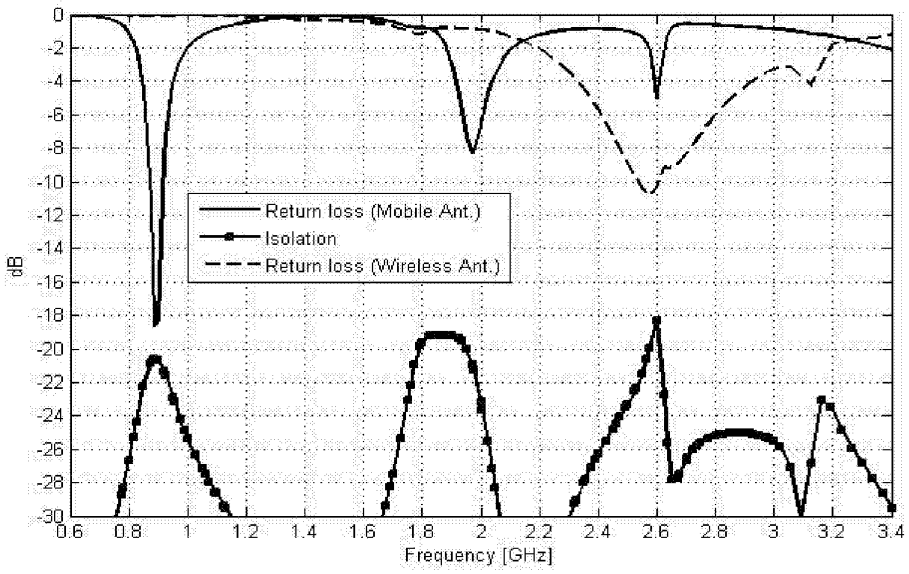
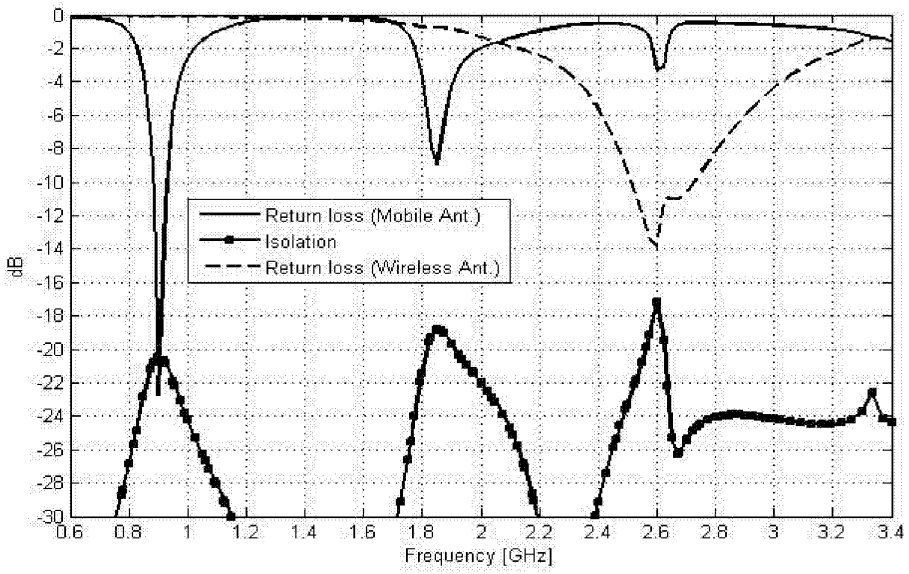


Fig. 2 (PRIOR ART)



(a)



(b)

Fig. 3 (PRIOR ART)

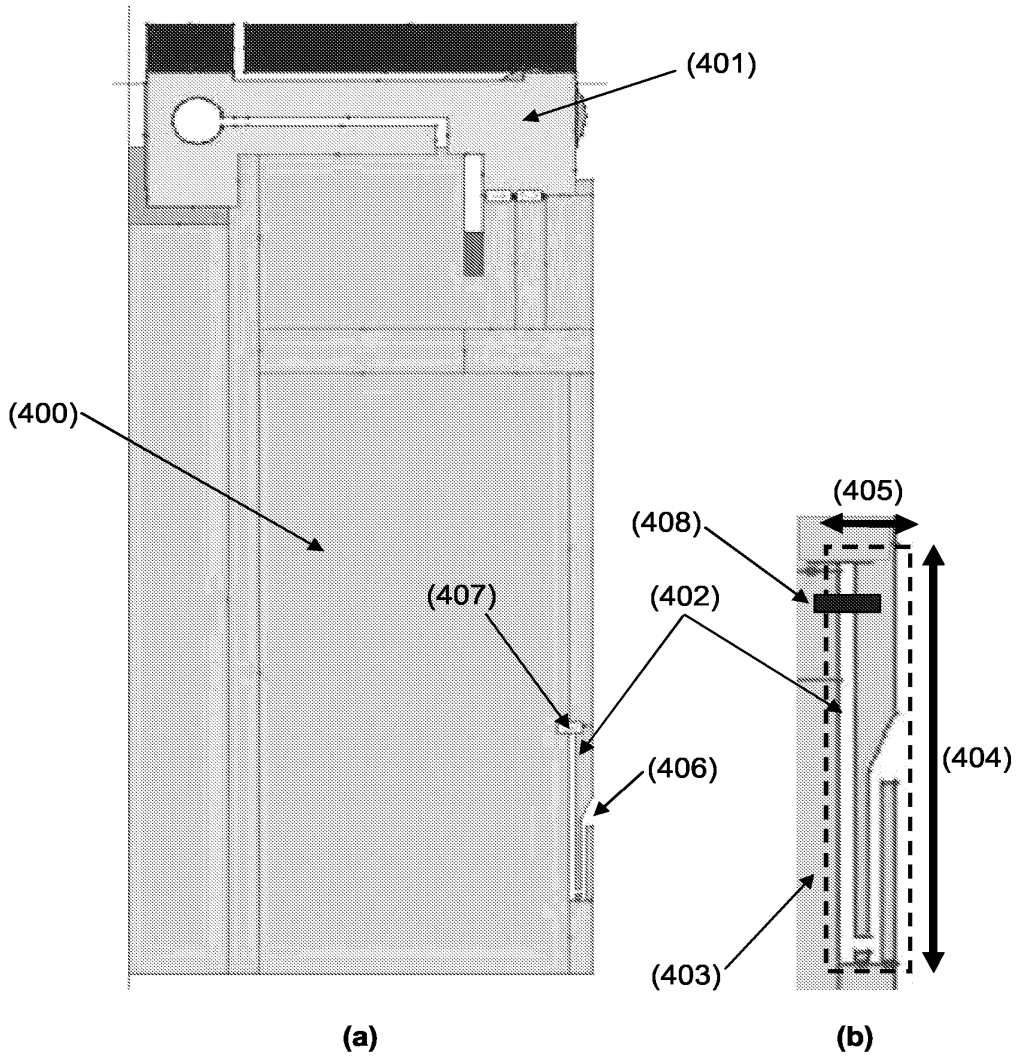
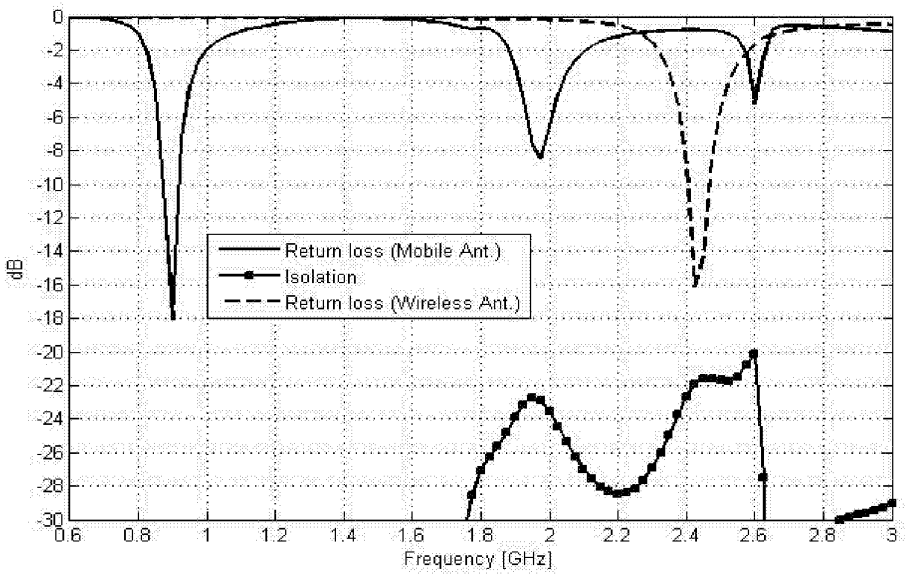
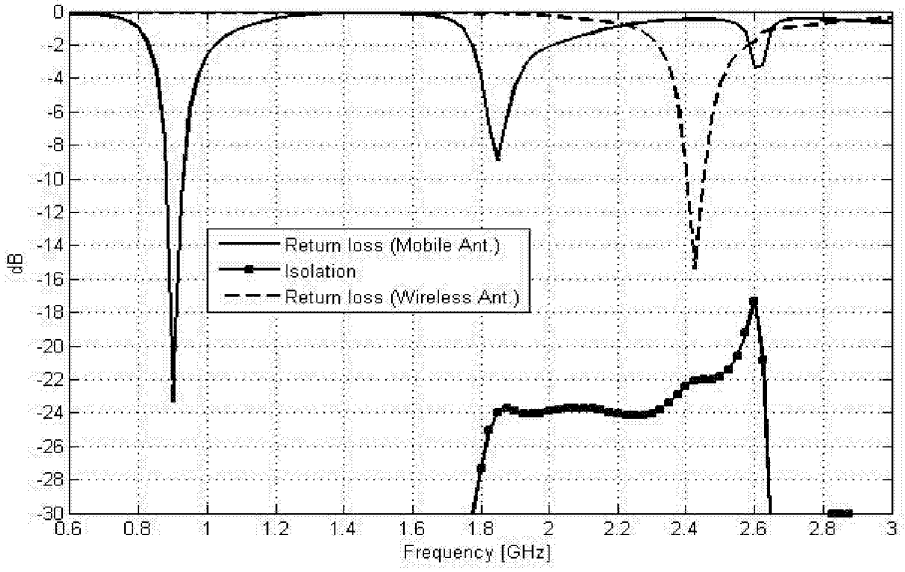


Fig. 4



(a)



(b)

Fig. 5

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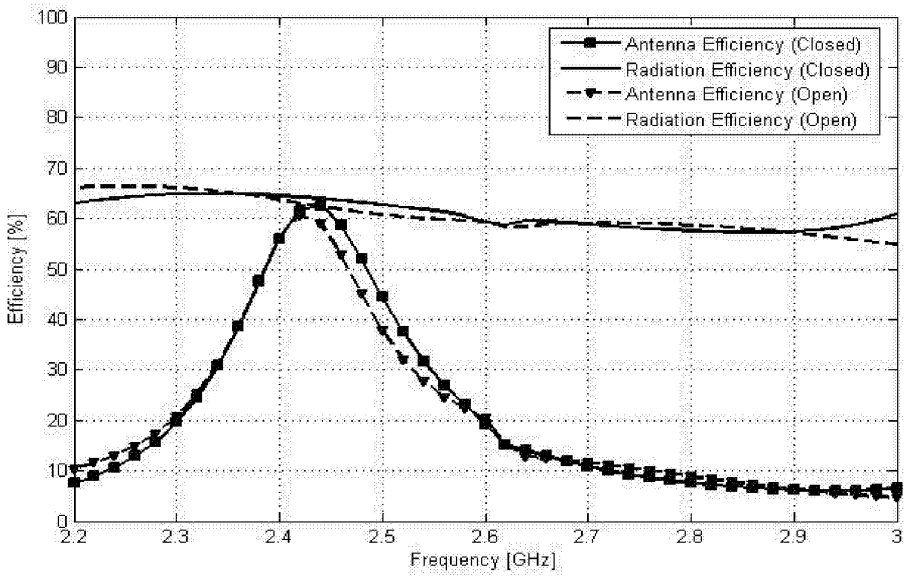


Fig. 6

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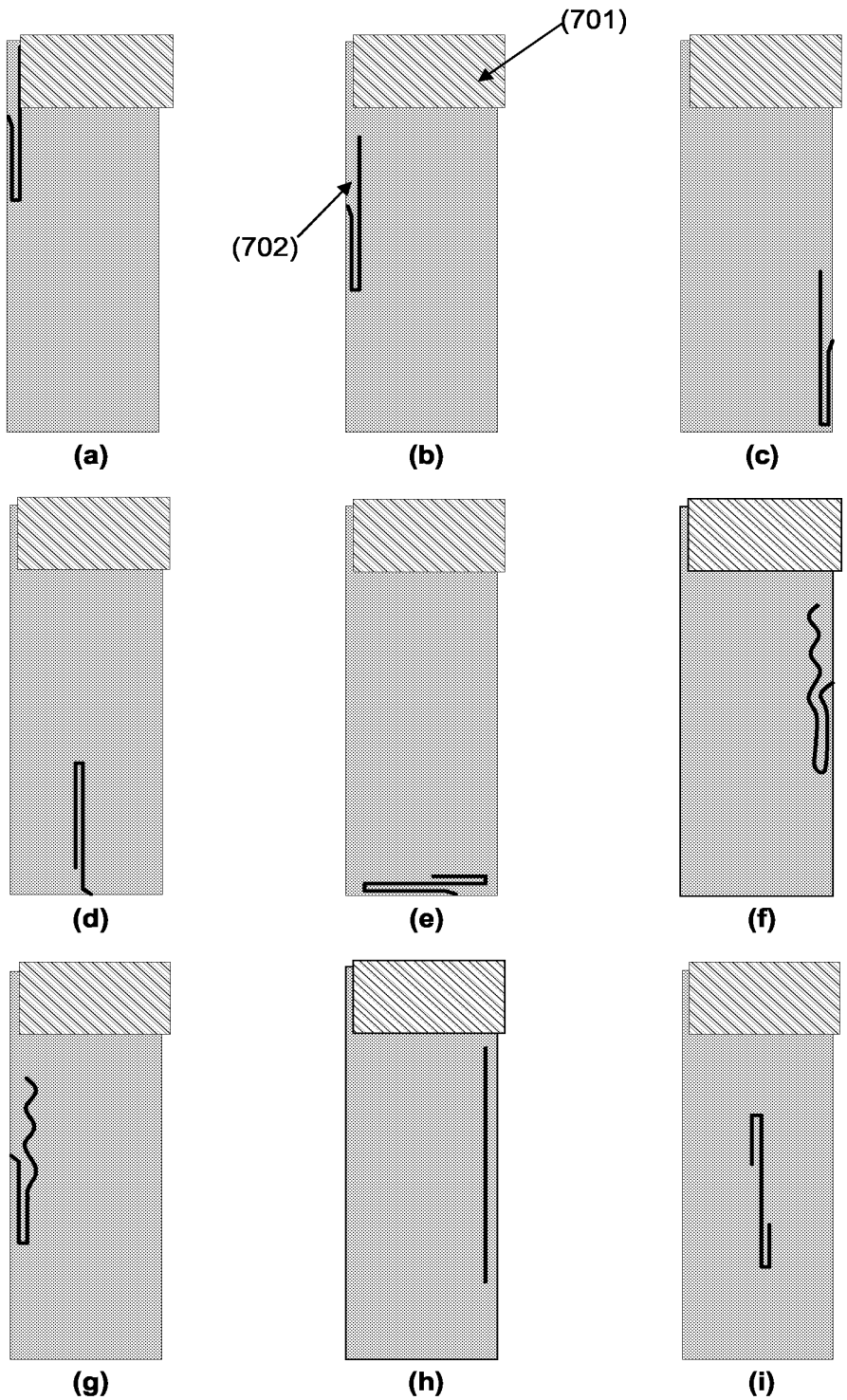
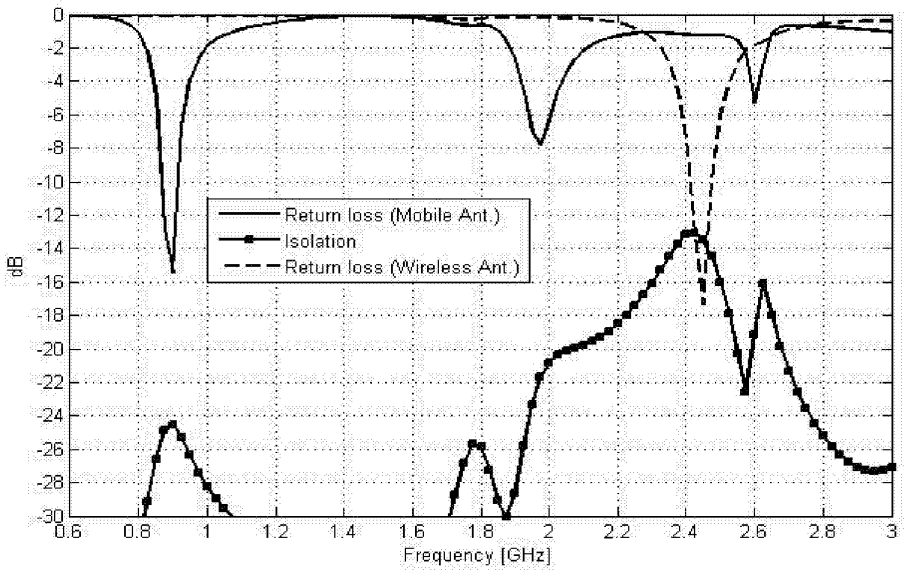
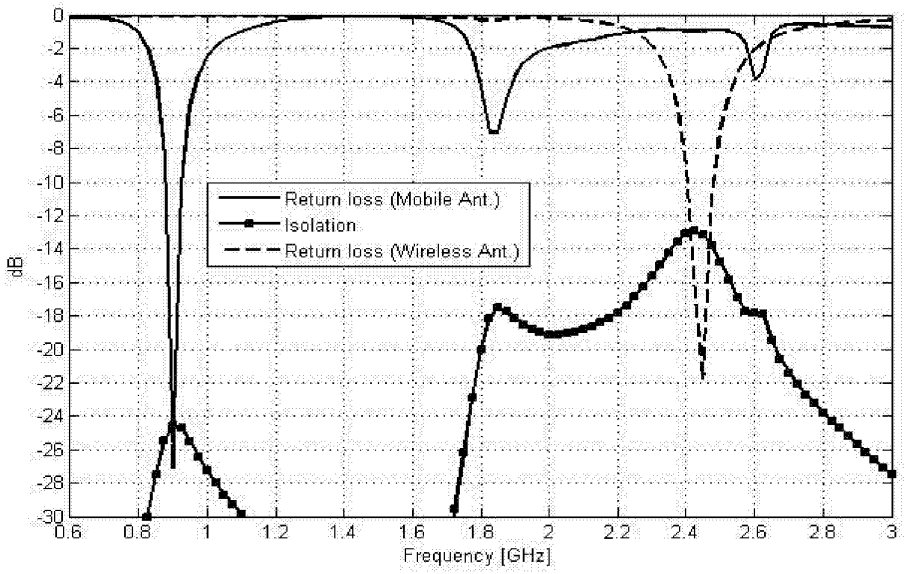


Fig. 7

Resmed Corp. - Ex. 1002
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(a)



(b)

Fig. 8

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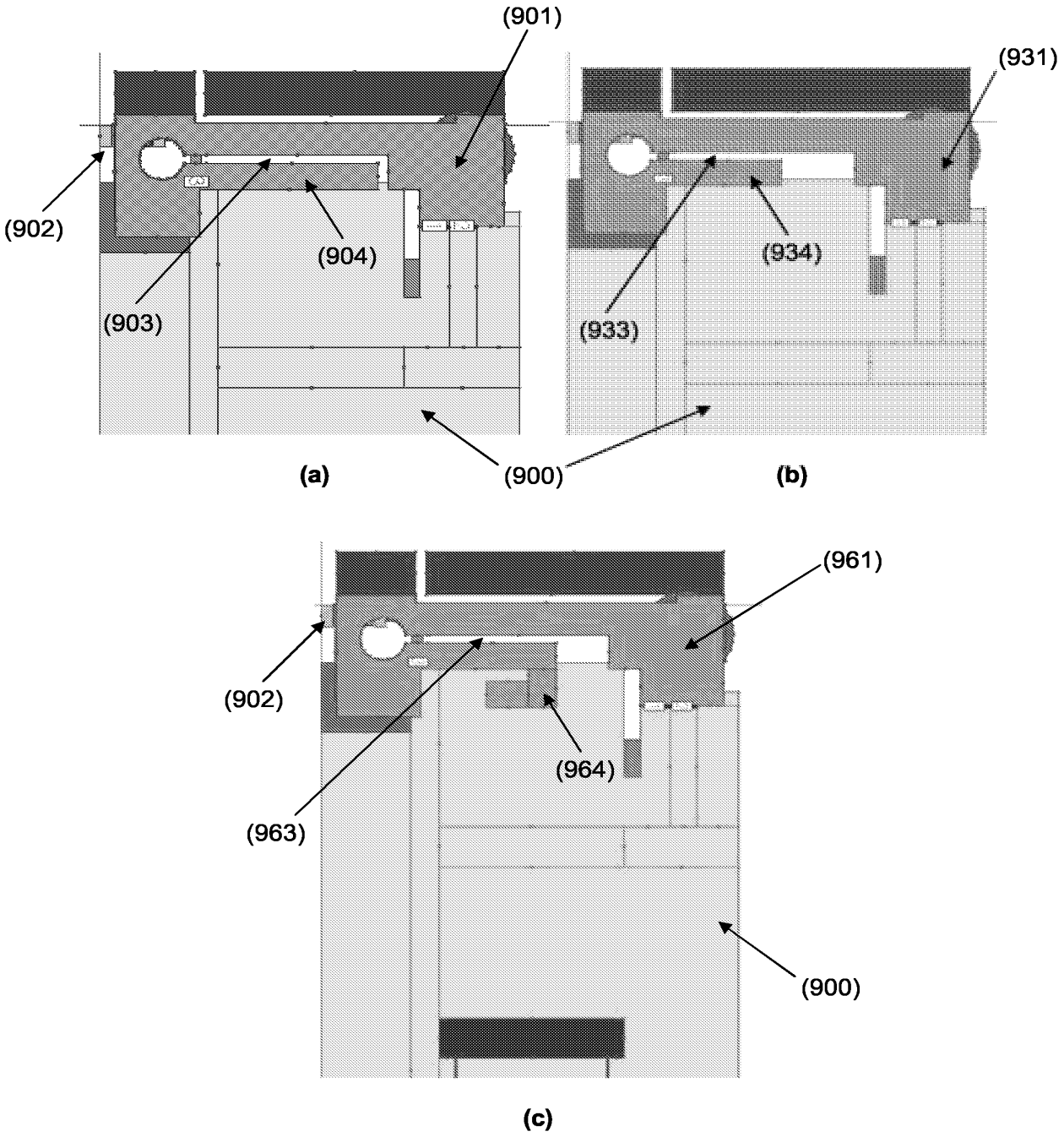


Fig. 9

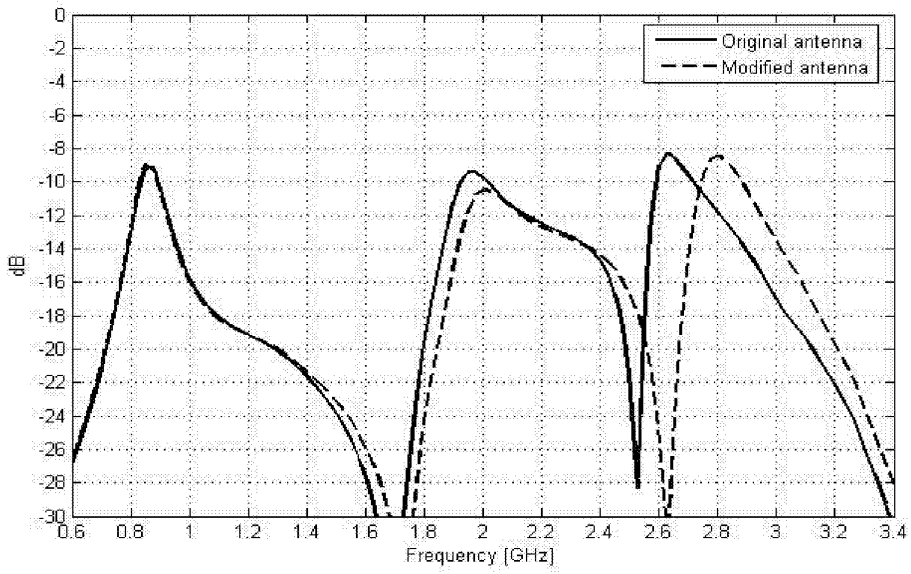
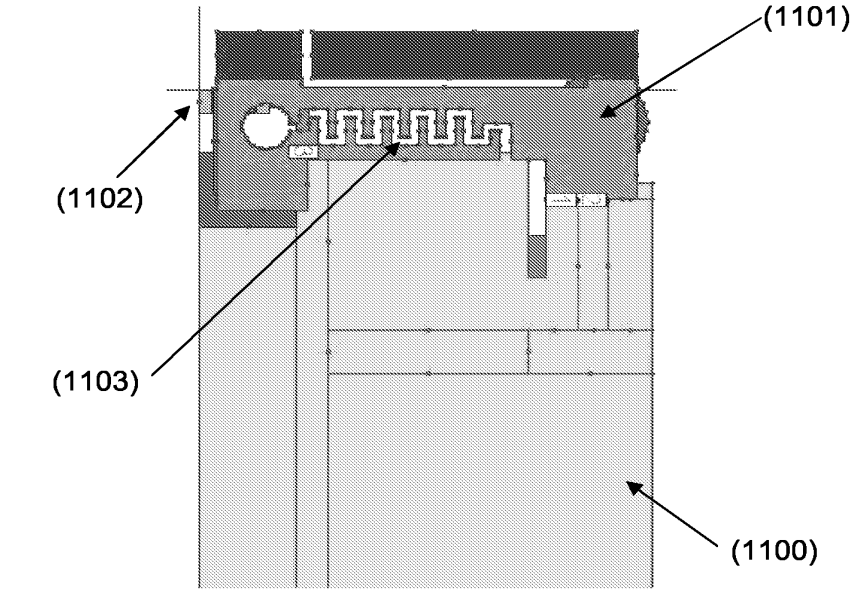
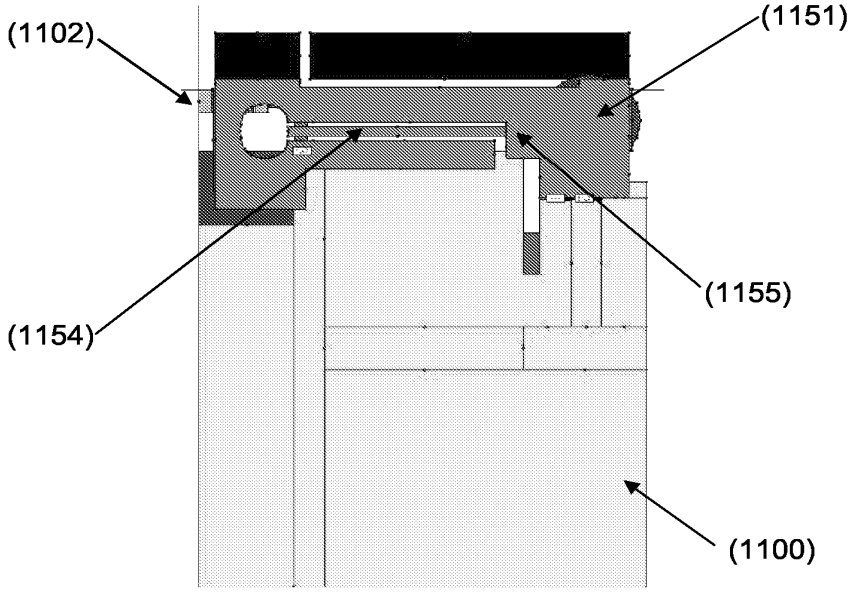


Fig. 10

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(a)



(b)

Fig. 11

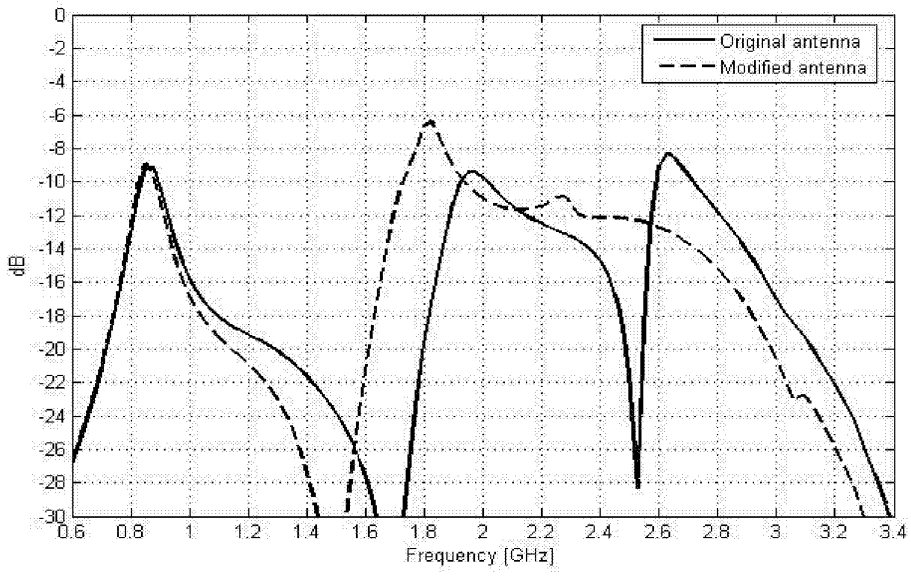
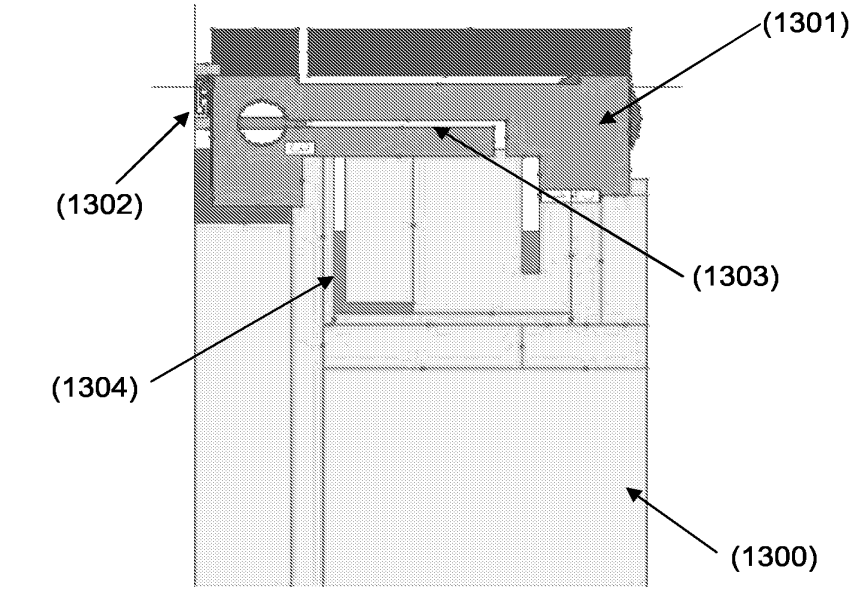
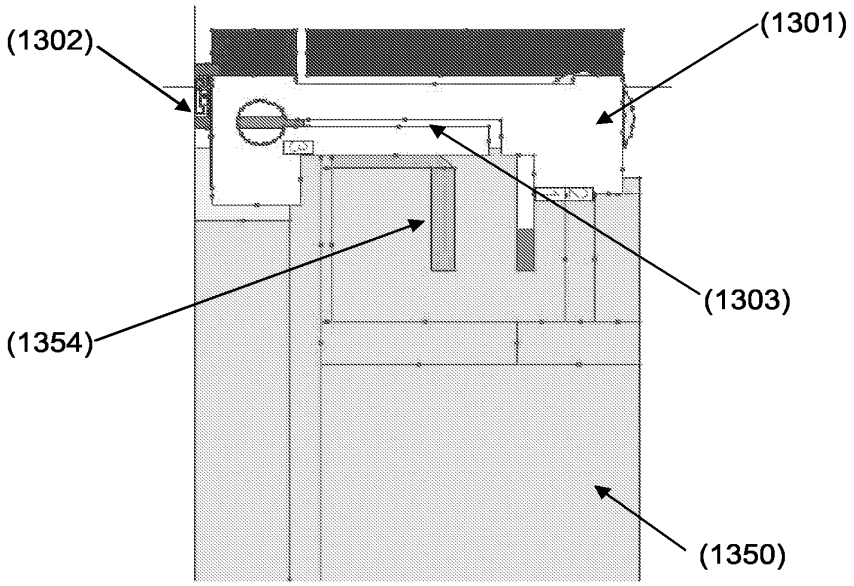


Fig. 12

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(a)



(b)

Fig. 13

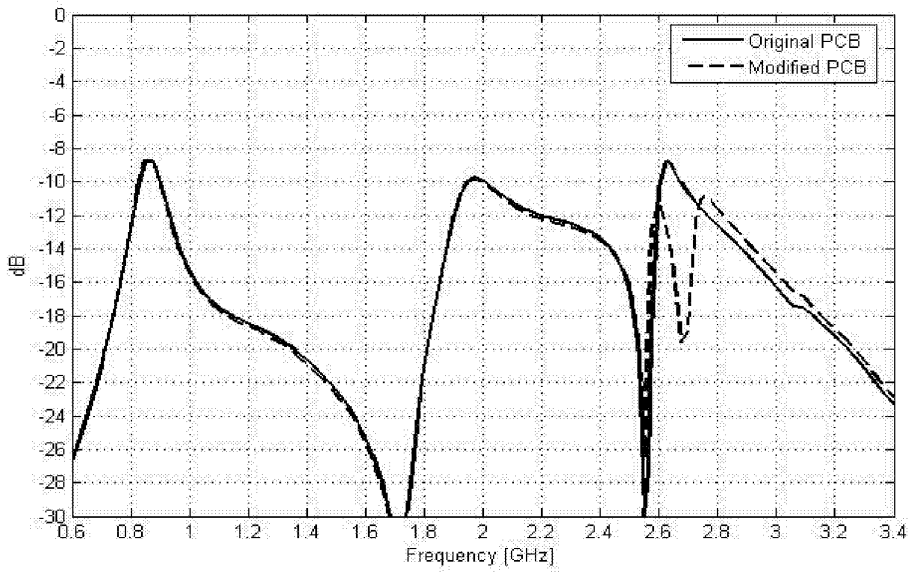
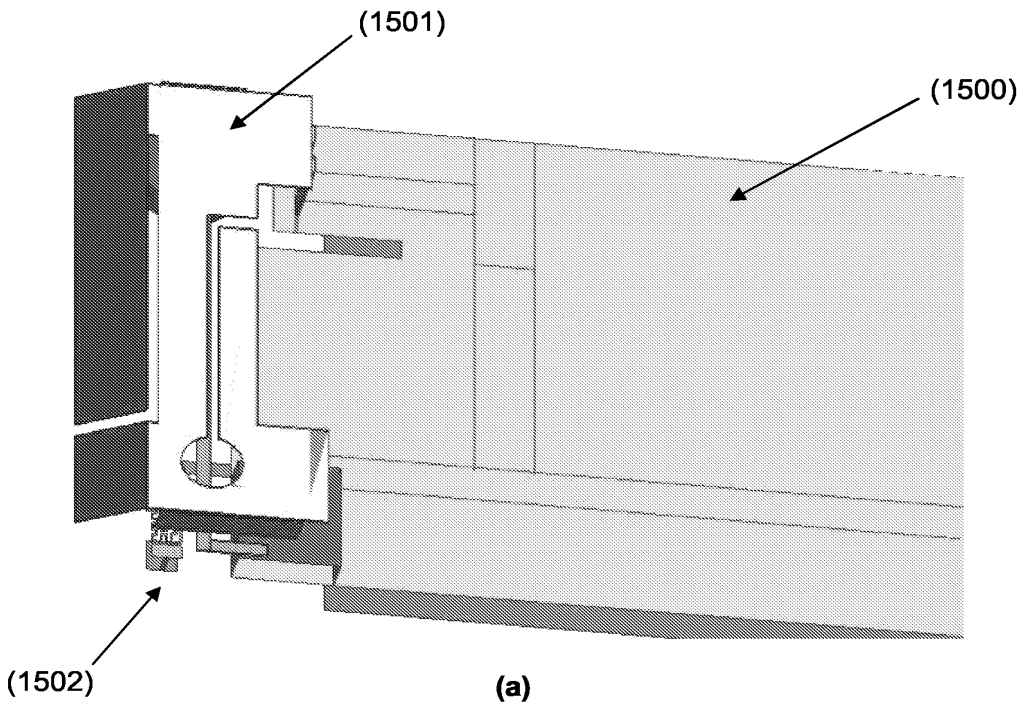
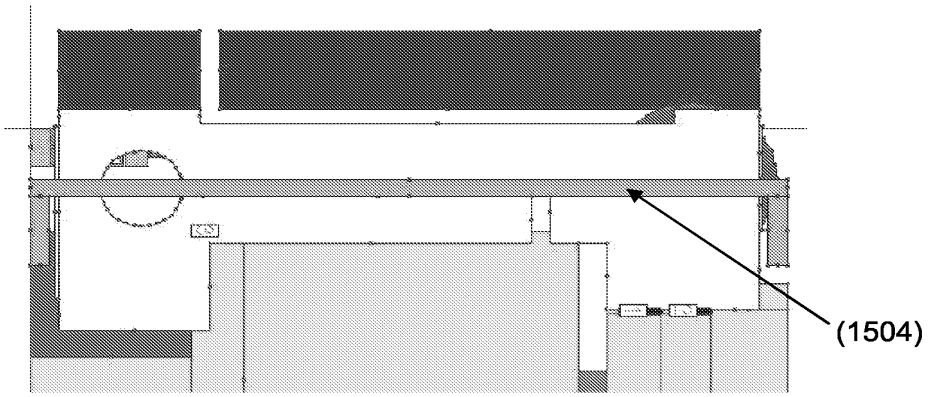

Original PCB
Modified PCB
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

Fig. 14



(a)



(b)

Fig. 15

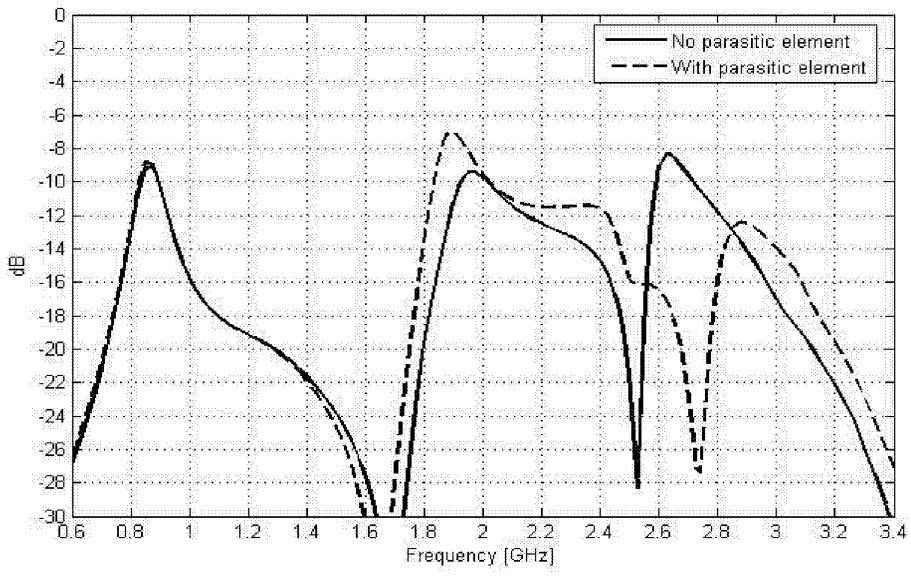

No parasitic element
With parasitic element
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

Fig. 16

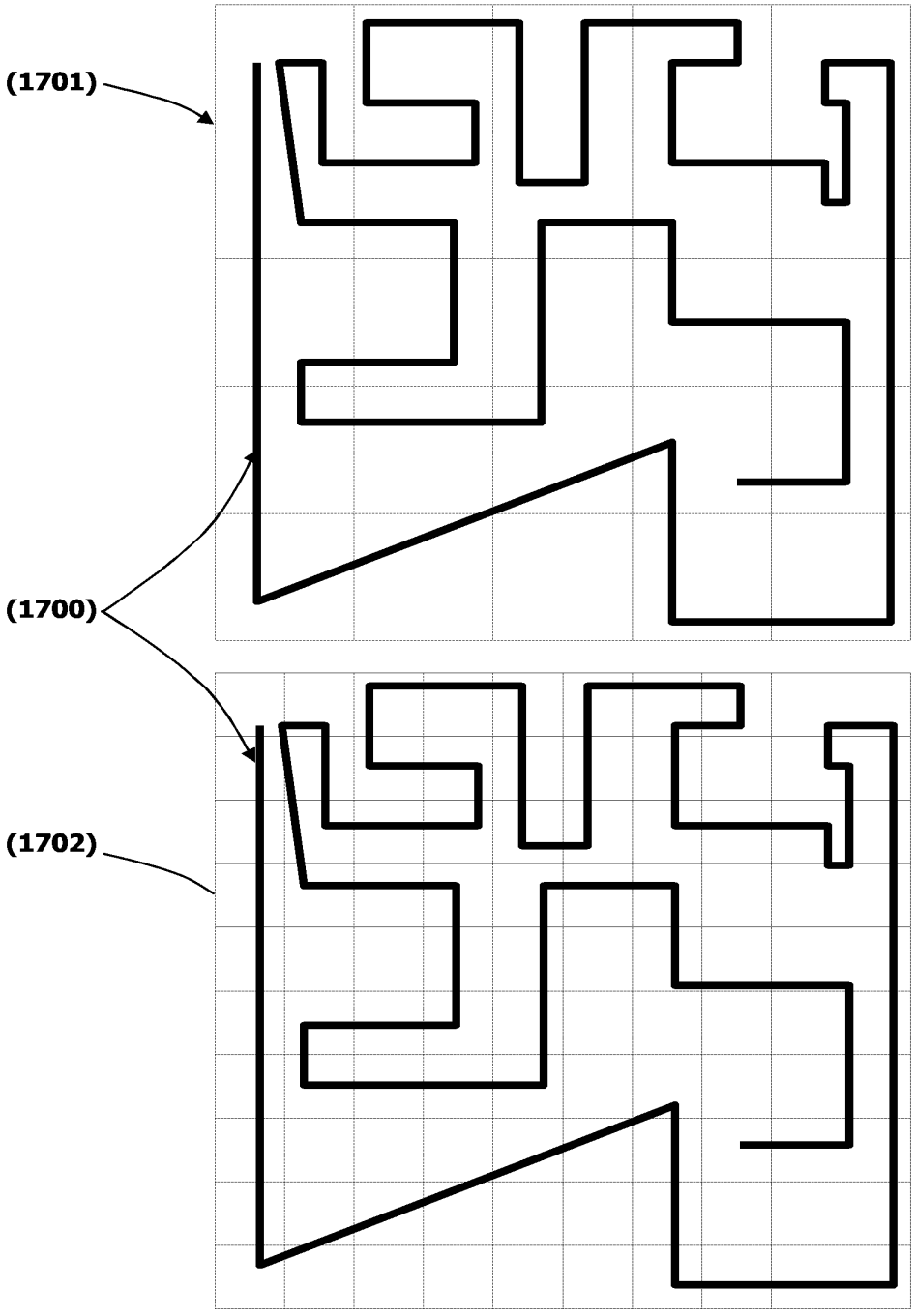


Fig. 17

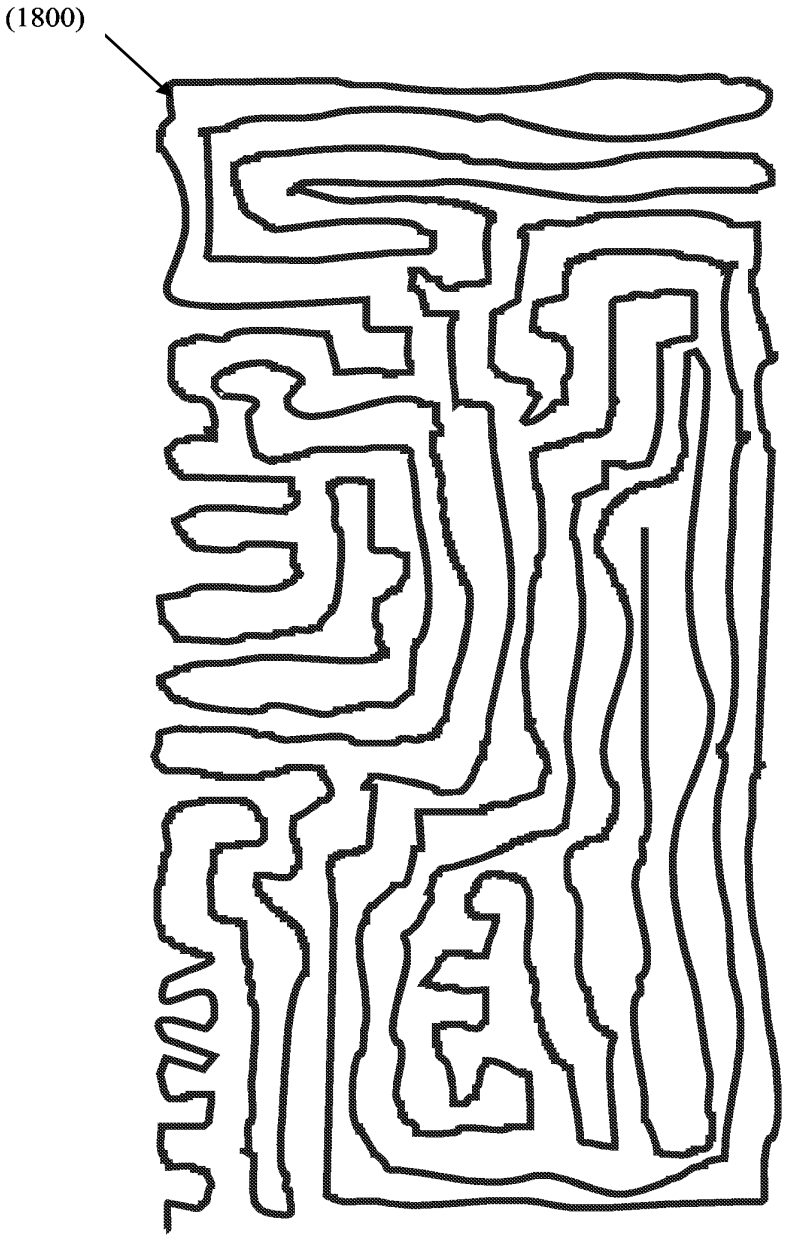


Fig. 18

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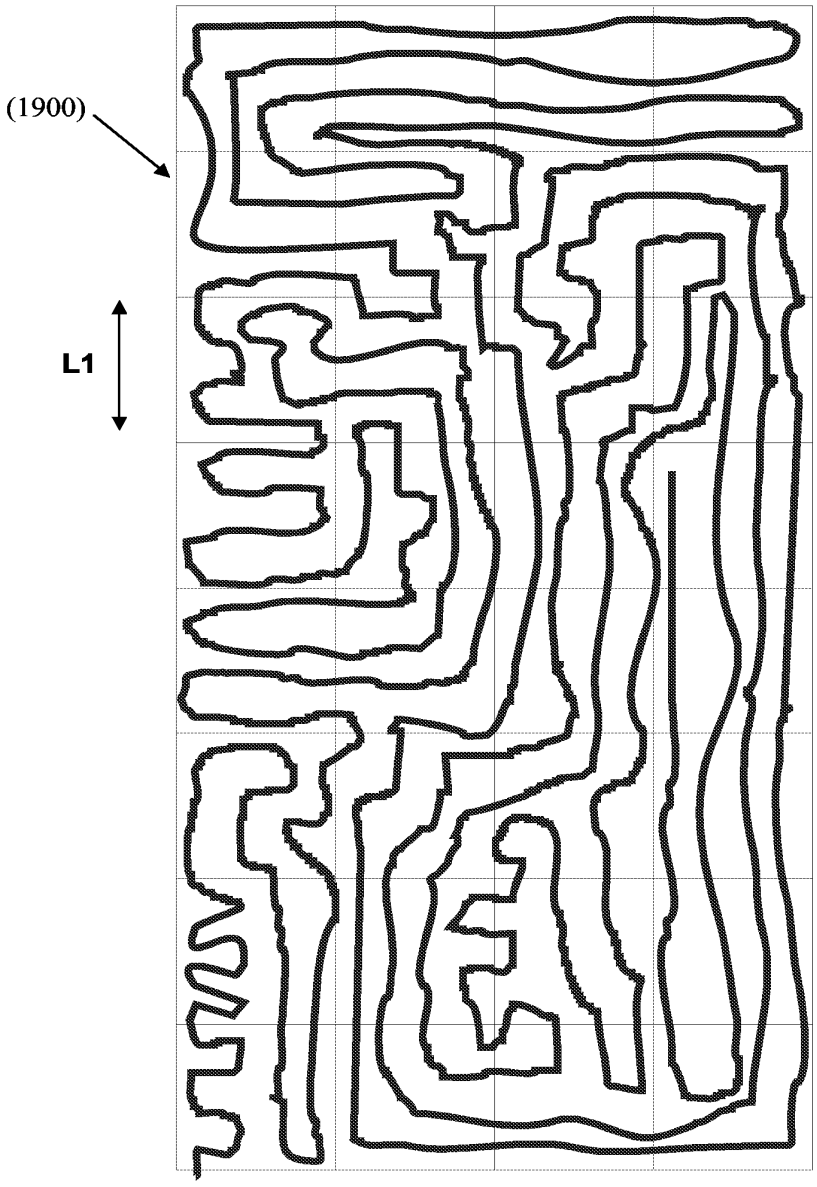


Fig. 19

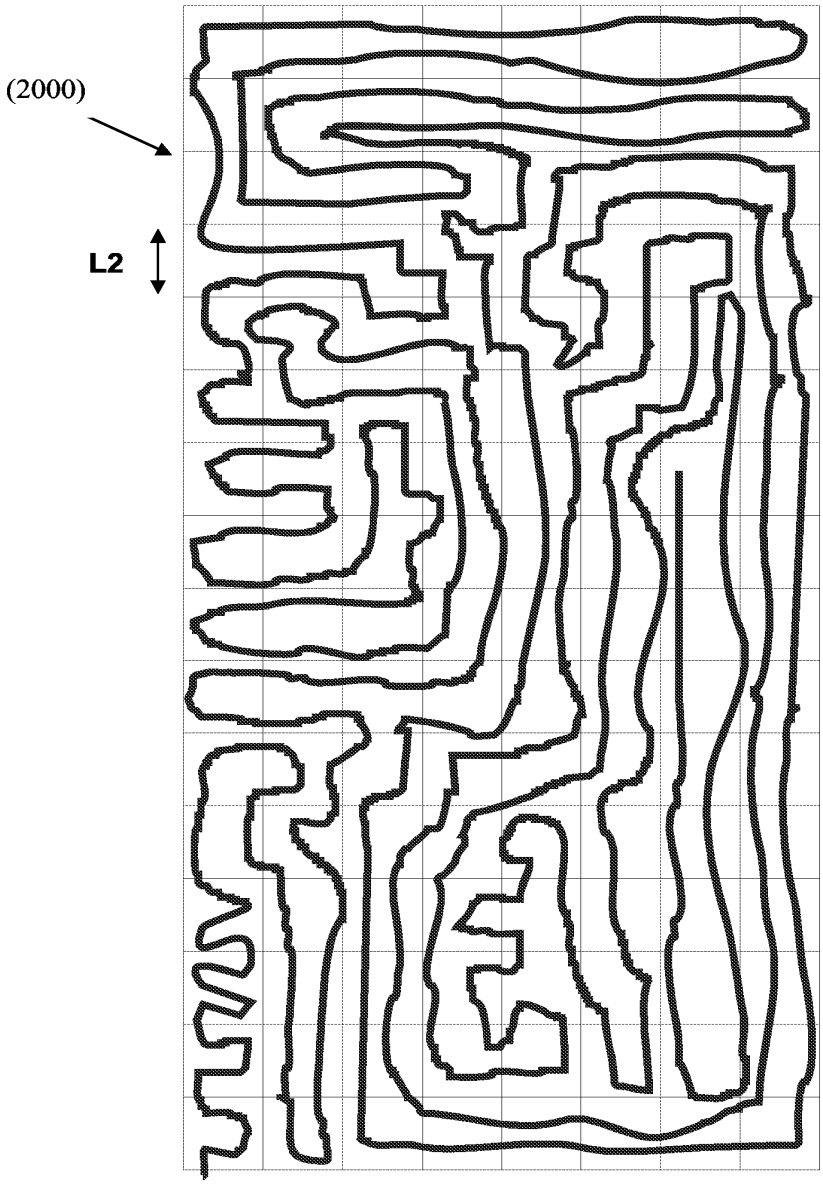


Fig. 20

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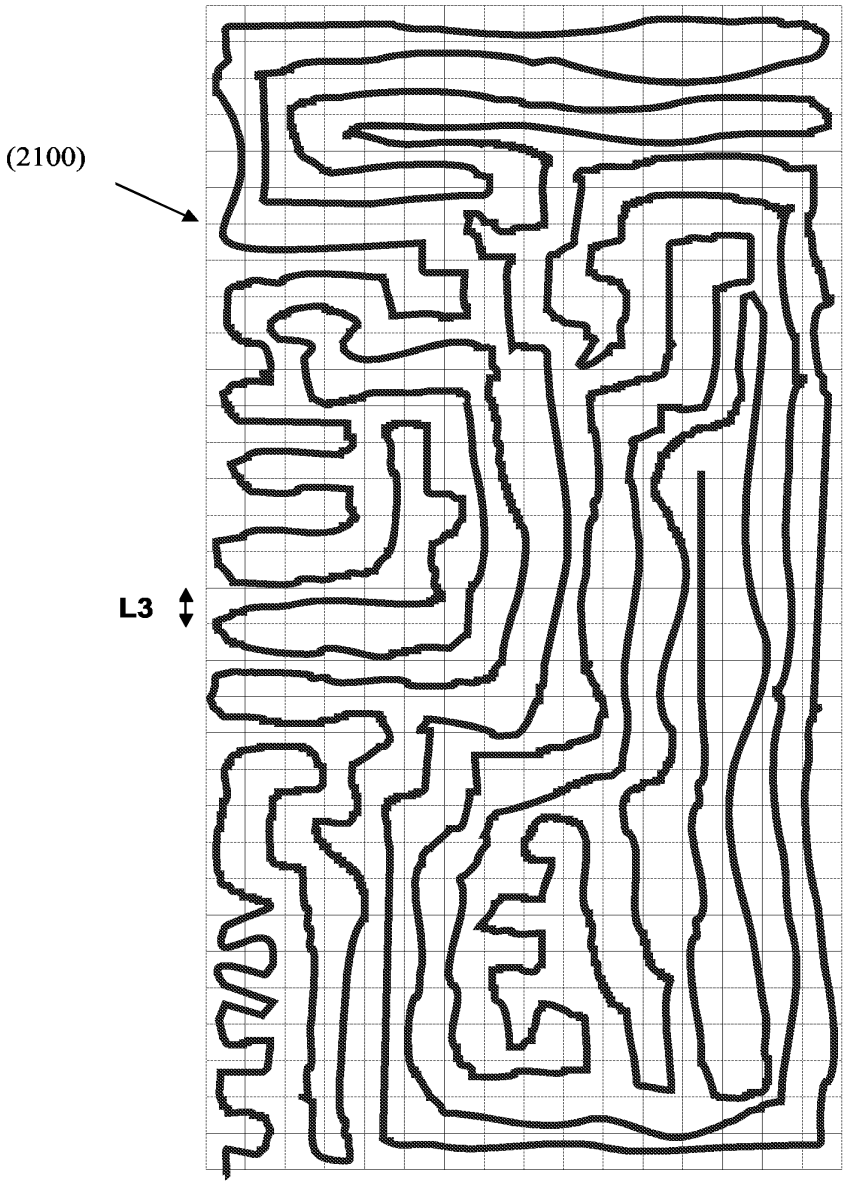


Fig. 21

PTO/SB/08a (01-10)
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Application Number	13341051
Filing Date	2011-12-30
First Named Inventor	Josep Mumbru
Art Unit	2821
Examiner Name	Not Yet Assigned
Attorney Docket Number	47005-P040WUSC1

U.S.PATENTS

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	2	5666125		1997-09-09	Luxon	
	3	5784032		1998-07-21	Johnston	
	4	5990838		1999-11-23	Burns et al	
	5	6204819		2001-03-20	Hayes et al	
	6	6337662		2002-01-08	Cassel	
	7	6424300		2002-07-23	Sandford	
	8	6606071		2003-08-12	Cheng et al	

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	Art Unit	2821
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	47005-P040WUSC1

	9	6624789		2003-09-23	Kangasvieri et al	
	10	6985108		2006-01-10	Mikkola et al	
	11	7170450		2007-01-30	Chang	

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	4	20070279289		2007-12-06	Baliarda et al	

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	First Named Inventor	Josep Mumbru
	Art Unit	2821
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	47005-P040WUSC1

	1	1401050	EP		2004-03-24	Filtronic LK Oy		☐
	2	1445821	EP		2004-08-11	Matsushita Electric Industrial Co		☐
	3	2005341313	JP		2005-12-08	Sharp KK		☒
	4	01/54225	WO		2001-07-21	Fractus SA		☐
	5	02/29929	WO		2002-04-11	Marconi Corporation		☐
	6	03/096475	WO		2003-11-20	Koninklijke Philips Electronics N.V.		☐
	7	2004/068631	WO		2004-08-12	Centurion Wireless Technologies Inc.		☐
	8	2004/102744	WO		2004-11-25	Koninklijke Philips Electronics NV		☐
	9	2004/105182	WO		2004-12-02	Antenova Limited		☐
	10	2005/076409	WO		2005-08-18	Fractus, SA		☐
	11	2006/120250	WO		2006-11-16	Fractus, SA		☐

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	1	FLOWS project - Antenna feasibility study on the printed antenna elements and the multiple input multiple output (MIMO) antenna topologies to be used in Flow mobile terminals, FLOWS project, November 18, 2002	☐
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	Examiner Name	Not Yet Assigned
	Attorney Docket Number	47005-P040WUSC1

	10	International search report and the written opinion of the International Searching Authority for PCT/EP2006/007050, EPO, December 13, 2006	☐
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	12	Notice of allowance for US patent application 11/988888, USPTO, October 14, 2011	☐
	13	Notice of allowance for US patent application 11/988888, USPTO, July 12, 2011	☐
	14	Amendment in response to non-final office action for US patent application 11/988888, Winstead, May 31, 2011	☐
	15	Office action for US patent application 11/988888, USPTO, January 10, 2011	☐
	16	Office action for US patent application 11/988888, USPTO, November 24, 2010	☐
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mounted as depicted in Fig. 13b (i.e., in such a way that the longer dimension of the component is aligned with the one of the longer edges of the PCB and substantially close to a corner of said edge), the polarization of the radiating mode of the antenna is tilted with respect to the radiating mode of the same slot-antenna component 110, 140, 160, 190, 200 mounted as depicted in Fig. 13a.

Space Filling Curves

In some examples, at least one antenna of the antenna diversity system may be miniaturized by shaping at least a portion of the conducting trace, conducting wire or contour of a conducting sheet of the antenna (e.g., a part of the arms of a dipole, the perimeter of the patch of a patch antenna, the slot in a slot antenna, the loop perimeter in a loop antenna, or other portions of the antenna) as a space-filling curve (SFC).

In some examples, at least one slot antenna of the slot-antenna component may be miniaturized by shaping at least a portion of the slot of said at least one slot antenna as a space-filling curve (SFC). Also a portion of a slot in a ground plane or a combined slot of a slot portion in a ground plane and a slot portion in an slot-antenna component may be shaped as a space filling curve.

A SFC is a curve that is large in terms of physical length but small in terms of the area in which the curve can be included. More precisely, for the purposes of this patent document, a SFC is defined as follows: a curve having at least five segments, or identifiable sections, that are connected in such a way that each segment forms an angle with any adjacent segments, such that no pair of adjacent segments define a larger straight segment. In addition, a SFC does not intersect with itself at any point except possibly the initial and final point (that is, the whole curve can be arranged as a closed curve or loop, but none of the lesser parts of the curve form a closed curve or loop).

A space-filling curve can be fitted over a flat or curved surface, and due to the angles between segments, the physical length of the curve is larger than that of any straight line that can be fitted in the same area (surface) as the space-filling curve.

Additionally, to shape the structure of a miniature antenna, the segments of the SFCs should be shorter than at least one fifth of the free-space operating wavelength, and possibly shorter than one tenth of the free-space operating wavelength. The space-filling curve should include at least five segments in order to provide some antenna size reduction, however a larger number of segments may be used. In general, the larger the number of segments, and the narrower the angles between them, the smaller the size of the final antenna.

Box-Counting Curves

In other examples, at least one antenna of the antenna diversity system may be miniaturized by shaping at least a portion of the conducting trace, conducting wire or contour of a conducting sheet of the antenna to have a selected box-counting dimension.

In other examples, at least one slot antenna of the slot-antenna component may be miniaturized by shaping at least a portion of the slot of said at least one slot antenna to have a selected box-counting dimension. Also a portion of a slot in a ground plane or a combined slot of a slot portion in a ground plane and a slot portion in an slot-antenna component may be shaped as a box-counting curve.

For a given geometry lying on a surface, the box-counting dimension is computed as follows. First, a grid with substantially squared identical cells boxes of size L1 is placed over the geometry, such that the grid completely covers the geometry, that is, no part of the curve is out of the grid. The number of boxes N1 that include at least a point of the geometry are then counted. Second, a grid with boxes of size L2 (L2 being smaller than L1) is also placed over the geometry, such that the grid completely covers the geometry, and the number of boxes N2 that include at least a point of the geometry are counted. The box-counting dimension D is then computed as:

$$D = -\frac{\log(N2) - \log(N1)}{\log(L2) - \log(L1)}$$

For the purposes of the antennas of the antenna diversity system described herein, the box-counting dimension may be computed by placing the first and second grids inside a minimum rectangular area enclosing the conducting trace, conducting wire or contour of a conducting sheet of the antenna and applying the above algorithm.

For the purposes of the slot antenna of the slot-antenna component described herein, the box-counting dimension may be computed by placing the first and second grids inside a minimum rectangular area enclosing the curve of the antenna and applying the above algorithm.

The first grid should be chosen such that the rectangular area is meshed in an array of at least 5 x 5 boxes or cells, and the second grid should be chosen such that L2 = 1/2 L and such that the second grid includes at least 10 x 10 boxes. The minimum rectangular area is an area in which there is not an entire row or column on the perimeter of the grid that does not contain any piece of the curve.

The desired box-counting dimension for the curve may be selected to achieve a desired amount of miniaturization. The box-counting dimension should be larger than 1.1 in order to achieve some antenna size reduction. If a larger degree of miniaturization is desired, then a larger box-counting dimension may be selected, such as a box-counting dimension ranging from 1.5 to 3. For the purposes of this patent document, curves in which at least a portion of the geometry of the curve has a box-counting dimension larger than 1.1 are referred to as box-counting curves.

For very small antennas, for example antennas that fit within a rectangle having maximum size equal to one-twentieth the longest free-space operating wavelength of the antenna, the box-counting dimension may be computed using a finer grid. In such a case, the first grid may include a mesh of 10 x 10 equal cells, and the second grid may include a mesh of 20 x 20 equal cells. The box-counting dimension (D) may then be calculated using the above equation.

In general, for a given resonant frequency of the antenna, the larger the box-counting dimension, the higher the degree of miniaturization that will be achieved by the antenna. One way to enhance the miniaturization capabilities of the antenna is to arrange the several segments of the curve of the antenna pattern in such a way that the curve intersects at least one point of at least 14 boxes of the first grid with 5 x 5 boxes or cells enclosing the curve. If a higher degree of miniaturization is desired, then the curve may be arranged to cross at least one of the boxes twice within the 5 x 5 grid, that is, the curve may include two non-adjacent portions inside at least one of the cells or boxes of the grid.

Fig. 22 illustrates an example of how the box-counting dimension of a curve 1200 is calculated. The example curve 1200 is placed under a 5 x 5 grid 1201 and under a 10 x 10 grid 1202. As illustrated, the curve 1200 touches N1=25 boxes in the 5 x 5 grid 1201 and touches N2=78 boxes in the 10 x 10 grid 1202. In this case, the size of the boxes in the 5 x 5 grid 1201 is twice the size of the boxes in the 10 x 10 grid 1202. By applying the above equation, the box-counting dimension of the example curve 1200 may be calculated as D=1.6415. In addition, further miniaturization is achieved in this example because the curve 1200 crosses more than 14 of the 25 boxes in grid 1201, and also crosses at least one box twice, that is, at least one box contains two non-adjacent segments of the curve. More specifically, the curve 1200 in the illustrated example crosses twice in 13 boxes out of the 25 boxes.

Grid Dimension Curves

In further examples, at least one antenna of the antenna diversity system may be miniaturized by shaping at least a portion of the conducting trace, conducting wire or contour of a conducting sheet of the antenna to include a grid dimension curve.

In further examples, at least one slot antenna of the slot-antenna component may be miniaturized by shaping at least a portion of the slot of said at least one slot antenna to include a grid dimension curve. Also a portion of a slot in a ground plane or a

combined slot of a slot portion in a ground plane and a slot portion in an slot-antenna component may be shaped as a box-counting curve.

For a given geometry lying on a planar or curved surface, the grid dimension of curve may be calculated as follows. First, a grid with substantially identical cells of size L1 is placed over the geometry of the curve, such that the grid completely covers the geometry, and the number of cells N1 that include at least a point of the geometry are counted. Second, a grid with cells of size L2 (L2 being smaller than L1) is also placed over the geometry, such that the grid completely covers the geometry, and the number of cells N2 that include at least a point of the geometry are counted again. The grid dimension D is then computed as:

$$D = -\frac{\log(N2) - \log(N1)}{\log(L2) - \log(L1)}$$

For the purposes of the antennas of the antenna diversity system described herein, the grid dimension may be calculated by placing the first and second grids inside the minimum rectangular area enclosing the curve of the antenna and applying the above algorithm.

For the purposes of the slot antenna of the slot-antenna component described herein, the grid dimension may be calculated by placing the first and second grids inside the minimum rectangular area enclosing the curve of the antenna and applying the above algorithm.

The minimum rectangular area is an area in which there is not an entire row or column on the perimeter of the grid that does not contain any piece of the curve.

The first grid may, for example, be chosen such that the rectangular area is meshed in an array of at least 25 substantially equal cells. The second grid may, for example, be chosen such that each cell of the first grid is divided in 4 equal cells, such that the size of the new cells is L2 = ½ L1, and the second grid includes at least 100 cells.

The desired grid dimension for the curve may be selected to achieve a desired amount of miniaturization. The grid dimension should be larger than 1 in order to achieve some antenna size reduction. If a larger degree of miniaturization is desired, then a larger grid dimension may be selected, such as a grid dimension ranging from 1.5 - 3 (e.g., in case of volumetric structures). In some examples, a curve having a grid dimension of about 2 may be desired. For the purposes of this patent document, a curve having a grid dimension larger than 1 is referred to as a grid dimension curve.

In general, for a given resonant frequency of the antenna, the larger the grid dimension the higher the degree of miniaturization that will be achieved by the antenna. One example way of enhancing the miniaturization capabilities of the antenna is to arrange the several segments of the curve of the antenna pattern in such a way that the curve intersects at least one point of at least 50% of the cells of the first grid with at least 25 cells enclosing the curve. In another example, a high degree of miniaturization may be achieved by arranging the antenna such that the curve crosses at least one of the cells twice within the 25-cell grid, that is, the curve includes two non-adjacent portions inside at least one of the cells or cells of the grid.

An example of a grid dimension curve 1300 is shown in Fig. 23. The grid dimension curve of Fig. 23 placed in a first grid 1400 is shown in Fig. 24. The same curve in a second grid 1500 is shwon in Fig. 25 and in a third grid 1600 in Fig. 26.

Multilevel Structures

In some examples, at least a portion of the conducting trace, conducting wire or conducting sheet of at least one antenna of the antenna diversity system may be coupled, either through direct contact or electromagnetic coupling, to a conducting surface, such as a conducting polygonal or multilevel surface.

In some examples, at least a portion of the slot of at least one slot antenna of the slot-antenna component may be coupled, either through direct contact or electromagnetic coupling, to a conducting surface, such as a conducting polygonal

or multilevel surface. Also the slot or a portion of a slot may be shaped as multilevel structure or polygonal.

A multilevel structure is formed by gathering several polygons or polyhedrons of the same type (e.g., triangles, parallelepipeds, pentagons, hexagons, circles or ellipses as special limiting cases of a polygon with a large number of sides, as well as tetrahedral, hexahedra, prisms, dodecahedra, etc.) and coupling these structures to each other electromagnetically, whether by proximity or by direct contact between elements. The majority of the component elements of a multilevel have more than 50% of their perimeter (for polygons) not in contact with any of the other elements of the structure. Thus, the component elements of a multilevel structure may typically be identified and distinguished, presenting at least two levels of detail: that of the overall structure and that of the polygon or polyhedron elements that form it.

Additionally, several multilevel structures may be grouped and coupled electromagnetically to each other to form higher-level structures. In a single multilevel structure, all of the component elements are polygons with the same number of sides or are polyhedrons with the same number of faces. However, this characteristic may not be true if several multilevel structures of different natures are grouped and electromagnetically coupled to form meta-structures of a higher level.

A multilevel antenna includes at least two levels of detail in the body of the antenna: that of the overall structure and that of the majority of the elements (polygons or polyhedrons) which make it up. This may be achieved by ensuring that the area of contact or intersection (if it exists) between the majority of the elements forming the antenna is only a fraction of the perimeter or surrounding area of said polygons or polyhedrons.

One example property of multilevel antennae is that the radioelectric behavior of the antenna can be similar in more than one frequency band. Antenna input parameters (e.g., impedance and radiation pattern) remain similar for several frequency bands (i.e., the antenna has the same level of adaptation or standing wave relationship in each different band), and often the antenna presents almost identical radiation

diagrams at different frequencies. The number of frequency bands is proportional to the number of scales or sizes of the polygonal elements or similar sets in which they are grouped contained in the geometry of the main radiating element.

In addition to their multiband behavior, multilevel structure antennae may have a smaller than usual size as compared to other antennae of a simpler structure (such as those consisting of a single polygon or polyhedron). Additionally, the edge-rich and discontinuity-rich structure of a multilevel antenna may enhance the radiation process, relatively increasing the radiation resistance of the antenna and reducing the quality factor Q (i.e., increasing its bandwidth).

A multilevel antenna structure may be used in many antenna configurations, such as dipoles, monopoles, patch or microstrip antennae, coplanar antennae, reflector antennae, wound antennae, antenna arrays, or other antenna configurations. In addition, multilevel antenna structures may be formed using many manufacturing techniques, such as printing on a dielectric substrate by photolithography (printed circuit technique); dieing on metal plate, repulsion on dielectric, or others.

While the invention has been described with respect to specific examples including presently preferred modes of carrying out the invention, those skilled in the art will appreciate that there are numerous variations and permutations of the above described systems and techniques that fall within the spirit and scope of the invention as set forth in the appended claims.

Claims

1.- An antenna diversity system comprising at least a first antenna and a second antenna wherein the first antenna substantially behaves as an electric current source or as a magnetic current source, and the second antenna substantially behaves as an electric current source or as a magnetic current source.

2. An antenna diversity system according to claim 1, wherein the first antenna (2) is an electric current source and the second antenna (3) is a magnetic current source.

3. An antenna diversity system according to claim 2, wherein the second antenna (3) is a slot antenna.

4. An antenna diversity system according to claim 2 or 3, wherein the first antenna (2) is selected from a group comprising: a monopole antenna, a patch antenna, an IFA (42), a PIFA and a multiband antenna (52).

5. An antenna diversity system according to claim 4, wherein the first antenna is printed as a conductive layer on a circuit board (4) or is etched from a conductive layer of a circuit board (4).

6. An antenna diversity system according to any of claims 3 to 5, wherein said slot antenna is inscribed in a rectangular area (7) the width (6) of which is smaller than 1/50 of a free-space operating wavelength, and/or the length (5) of which is smaller than 1/4 of a free-space operating wavelength.

7. An antenna diversity system according to claim any of claims 3 to 6, wherein said slot antenna is inscribed in a rectangular area (7) the width (6) of which divided by a free-space operating wavelength is smaller than, or equal to, at least one of the fractions of the group comprising: 1/10, 1/30, 1/50, 1/60, 1/70, or 1/80.

8. An antenna diversity system according to any of claims 3 to 7, wherein said slot antenna is inscribed in a rectangular area (7) the length (5) of which divided by a

free-space operating wavelength of the said slot antenna is smaller than, or equal to, at least one of the fractions of the group comprising: 1/2, 1/3, or 1/4.

9. An antenna diversity system according to any of claims 3 to 7, wherein said slot antenna is inscribed in a rectangular area (7) the length (5) of which divided by a free-space operating wavelength of the said slot antenna is smaller than, or equal to, at least one of the fractions of the group comprising: 1/5, 1/6 and 1/8.

10. An antenna diversity system according to any of the claims 3 to 9, wherein the said slot antenna (3) is printed as a conductive layer on a circuit board (4) or etched from a conductive layer of a circuit board (4).

11. An antenna diversity system according to claim 10, wherein said conductive layer is capable of operating as a ground plane of the antenna system of the antenna diversity system (1).

12. An antenna diversity system according to any of the claims 3 to 11, wherein the slot comprises at least one, two, three, four, five or more substantially straight and/or curved segment/segments, of which one, two, three, four, five or more preferably have the same or different length.

13. An antenna diversity system according to claim 12, wherein the separation between the edges of at least one, two, three, four, or more segments is the same and/or constant.

14. An antenna diversity system according to claim 12 or 13, wherein the separation between the edges of at least one, two, three, four, or more segments is within a minimum and a maximum fraction of a free-space operating wavelength of said slot antenna, wherein said minimum and maximum fraction are selected from the set comprising: 0.08%, 0.16%, 0.32%, 0.5%, 1%, 2%, 4%, 6%, and 8%.

15. An antenna diversity system according to any of claims 12 to 14, wherein the longest segment, preferably the longest straight segment, of the slot is substantially parallel to the longest edge, extension or symmetry axis of a circuit board (4).

16. An antenna diversity system according to any of claims 3 to 15, wherein the slot has an open end which is provided at one edge of a circuit board (4).

17. An antenna diversity system according to any of the claims 3 to 9, wherein the said slot antenna is embedded in a component that can be or is mounted on a circuit board (4) such as for example an SMT component.

18. An antenna diversity system according to claim 17, wherein the slot (3) comprises at least one, two three, four, five or more substantially straight and/or curved segments, of which one, two, three, four five or more preferably have the same or different length.

19. An antenna diversity system according to claim 18, wherein the separation between the edges of at least one, two, three, four, or more segments is the same and/or constant.

20. An antenna diversity system according to claim 18 or 19, wherein the separation between the edges of at least one, two, three, four, or more segments is within a minimum and a maximum fraction of a free-space operating wavelength of said slot antenna, wherein said minimum and maximum fraction are selected from the set comprising: 0.08%, 0.16%, 0.32%, 0.5%, 1%, 2%, 4%, 6%, and 8%.

21. An antenna diversity system according to any of claims 18 to 20, wherein the longest segment, preferably the longest straight segment, of the slot (3) is substantially parallel to the longest edge, extension or symmetry axis of the component.

22. An antenna diversity system according to any of claims 17 to 21, wherein said slot (3) has an open end which is provided at one edge of the component or a conductive layer of said component.

23. An antenna diversity system according to any of claims 3 to 22, wherein at least two, three, four or more portions of said slot (3) are parallel to each other.

24. An antenna diversity system according to any of claims 3 to 23, wherein the area of a smallest possible rectangular area which completely encloses the slot of the slot antenna (3) or the perpendicular projection of the slot onto the plane of the circuit board (4) divided by the area of the circuit board is equal to or less than a fraction of the group comprising: 1/5, 1/7, 1/10, 1/15, 1/20, 1/15, 1/30, 1/40, 1/50, 1/60, 1/70, 1/80, 1/90, 1/100, 1/120, 1/140, 1/160, 1/180, 1/200, 1/250, 1/300, 1/400, 1/500, 1/1000.

25. An antenna diversity system according to any of claims 1 to 24, wherein the electric currents excited on at least a portion of the circuit board (4) by the radiating mode of the said first antenna (2) are substantially parallel to the magnetic currents excited on at least a portion of the extension of the said second antenna (3).

26. An antenna diversity system according to claim 1, wherein the first antenna (102) and the second antenna (103) is a magnetic current source.

27. An antenna diversity system according to claim 26, wherein the first and/or the second antenna are slot antennas (102, 103).

28. An antenna diversity system according to claim 27, wherein the longest portion of the first slot antenna (102) and the second slot antenna (103) or extension or side of a smallest enclosing rectangle of the first slot antenna and the (102) second slot antenna (103) are substantially perpendicular.

29. An antenna diversity system according to claim 27 or 28, wherein the first slot antenna (102) has an open end on a first edge of a circuit board (4) and the second slot antenna (103) has an open end on a second edge of said circuit board (4), said first and second edges being substantially perpendicular.

30. An antenna diversity system according to any of claims 26 to 29, wherein the magnetic currents excited on at least a portion of the extension of the first antenna (102) are substantially orthogonal to the magnetic currents excited on at least a portion of the extension of the second antenna (103).

31. An antenna diversity system according to claim 1, wherein the first antenna and the second antenna behave as electric current sources.

32. An antenna diversity system according to claim 31, wherein the electric currents excited on a printed circuit board, by the radiating mode of the first antenna, are substantially orthogonal to the electric currents excited on the said printed circuit board by the radiating mode of the second antenna, in at least a portion of the printed circuit board.

33. An antenna diversity system according to any of claims 31 or 32, wherein the first and/or the second antenna is selected from the group comprising: a monopole antenna, patch antenna, IFA, a PIFA and a multiband antenna.

34. An antenna diversity system according to any of claims 1 to 33, wherein said first antenna (2) of the said at least two antennas is radiating with a first polarization, and said second antenna (3) of the said at least two antennas is radiating with a second polarization, wherein the said first polarization and second polarization are substantially orthogonal.

35. An antenna diversity system according to any of claims 1 to 34, wherein the first and/or the second antenna (2, 3) is/are multiband antenna/antennas having one, two three or more frequency bands in common.

36. An antenna diversity system according to any of claims 1 to 35, wherein the first and/or the second antenna (2, 3) are located on a corner or not separated more than 1%, 5%, 10% or 20% of the longest circuit board extension (76) or respective antenna extension from a corner of a circuit board carrying the antennas.

37. An antenna diversity system according to any of claims 1 to 36, wherein the first and/or the second antenna (2,3) are located on an edge (73) of a circuit board (4) carrying the antennas or not further separated from the edge than 1%, 5%, 10 % or 20 % than the longest extension (76) of the circuit board (4) or of the longest extension of the respective antenna.

38. Antenna diversity system according to any of claims 1 to 37, wherein the first and/or second antenna (2, 3) are covering the middle (74) of an edge (73) or is/are not more separated from the middle (74) than 1%, 5%, 10 % or 20% than the longest extension of the circuit board (4) or the extension (e1, e2) of the antenna (72) in the respective direction.

39. Antenna diversity system according to any of claims 1 to 38, wherein the separation (79) between first and second antenna (77, 78) is not more than a percentage of the longest extension (76) of a circuit board (4) carrying the antennas (2, 3), the percentage being chosen from the group comprising: 1%, 2%, 3%, 5%, 7%, 10%, 12%, 15%, 20%, 30%, 40% and 50%.

40. Antenna diversity system according to any of claims 1 to 39, wherein the separation (79) between the first antenna (77) and the second antenna (78) is more than a percentage of the longest extension (76) of a circuit board carrying the antennas, the percentage being chosen from the group comprising: 50%, 60%, 70%, 75%, 80%, 85%, 90% and 95 %.

41. An antenna diversity system according to any of claims 1 to 40, wherein at least the first and/or the second antenna (2, 3) is integrated each in a respective semiconductor package.

42. An antenna diversity system according to claim 41, wherein at least one or two of said semiconductor packages include an electronic circuit.

43. An antenna diversity system according to claim 42, wherein said electronic circuit comprises an electronic die.

44. An antenna diversity system according to any of claims 1 to 43, wherein at least one of the said at least two antennas (2, 3) is operating not only in the same frequency band as the other antennas, but is also operating, at least, at some other frequency band used for mobile telephone systems.

45. An antenna diversity system according to any of claims 1 to 44, wherein at least a portion which defines the conducting trace, conducting wire or contour of at least one of the antennas (2, 3), or at least a portion of a slot (113) or the entire slot (113), is shaped as a space-filing curve, or a box-counting, or a grid dimension curve or a fractal curve.

46. An antenna diversity system according to any of claims 1 to 45, wherein at least a portion of at least one of the antennas (2, 3) is a polygonal or multilevel structure or coupled to a polygonal or multilevel structure.

47. An antenna diversity system comprising at least a first antenna (3) and a second antenna (2), and a circuit board (4) such as a printed circuit board on which the said at least first antenna (3) and second antenna (2) are mounted, printed or etched;

wherein the first antenna (3) substantially behaves as a magnetic current source and the second antenna (2) substantially behaves as an electric current source;

wherein said first antenna (3) of the said at least two antennas is radiating with a first polarization, and said second antenna (2) of the said at least two antennas is radiating with a second polarization, wherein the said first polarization and second polarization are substantially orthogonal;

wherein the said first antenna (3) is a slot antenna, wherein the longest straight segment of the slot (3) is substantially parallel to the longest edge of the said

circuit board (4), wherein one open end of the slot (3) is in contact with one edge of the said circuit board (4);

wherein the width of the rectangular area (7) in which the said slot antenna is inscribed, divided by a free-space operating wavelength of the said slot antenna is smaller than, or equal to, at least one of the following fractions: 1/10, 1/30, 1/50, 1/60, 1/70, or 1/80;

and wherein the length of the rectangular area (7) in which the said slot antenna (3) is inscribed, divided by a free-space operating wavelength of the said slot antenna is smaller than, or equal to, at least one of the following fractions: 1/2, 1/3, or 1/4.

48. A wireless device including an antenna diversity system according to any of the preceding claims.

49. A wireless device according to claim 48, wherein the device is at least one or a combination of wireless devices of a group of wireless devices comprising: a cellular phone, a mobile phone, a handheld phone, a smart phone, a satellite phone, a multimedia terminal, personal digital assistant (PDA), a portable music player, a radio, a digital camera, a USB dongle, a wireless headset, an ear phone, a hands-free kit, an electronic game, a remote control, an electric switch, a light switch, an alarm, a car kit, a computer card, a PCMCIA card, a sensor, a headset, a dongle, a computer interface a computer mouse, a keyboard, a personal computer, a MP3 player, a portable DVD/CD player, a smoke detector, a switch, a motion sensor, a pressure sensor, a temperature sensor, a medical sensor, a meter, a short/medium range wireless connectivity application, a Mini-PCI, a Notebook, PC with WiFi module integrated, a compact flash wireless card, a UART dongle, a pocket PC with integrated Wi-Fi, an access point for a hot spot, a wireless wrist watch, a wireless wrist sensor, a bracelet FM radio, an MP3 player, a radio frequency identification tag, key remote entry system, an air pressure sensor e.g. in a tire, a radio controlled toy, a laptop and a cardbus 32 card.

50. A wireless device according to any of claims 48 or 49, wherein the device is configured for operation in one, two, three or more of the wireless communication

systems preferably selected from the group comprising: Bluetooth, 2.4GHz Bluetooth, 2.4 GHz WiMAX, ZigBee, ZigBee at 860 MHz, ZigBee at 915 MHz, GPS, GPS at 1.575 GHz, GPS at 1.227 GHz, Galileo, GSM 450, GSM 850, GSM 900, GSM 1800, American GSM, DCS-1800, UMTS, CDMA, DMB, WLAN, WLAN at 2.4 GHz-6GHz, PCS 1900, KPCS, WCDMA, SDARs, XDARS, DAB, WiFi, UWB, 2.4-2.483 GHz band, 2.471-2.497 GHz band, IEEE802.11ba, IEEE802.11b, IEEE802.11g and FM.

51. A wireless device according to any of claims 48 or 49, wherein the device is configured for operation in at least the DVB-H wireless communication system.

52. An SMT-type slot-antenna component (110) comprising:
- at least one conductive surface (111) or sheet of metal in which the pattern of a slot (113) is created;
- at least one contact terminal (105) accessible from the exterior of said component to electrically connect the conductive surface included in the slot-antenna component with the ground plane of a circuit board such as a printed circuit board (121);

53. The SMT-type slot-antenna component according to claim 52, further comprising a dielectric substrate that backs the conductive surface (111) or sheet of metal or in which said conducting surface or sheet of metal is embedded.

54. The SMT-type slot-antenna component according to claim 52 or 53, which does or does not form part of an antenna diversity system.

55. The SMT-type slot-antenna component according to any of claims 52 to 54, further comprising at least one contact terminal (114) to couple a radio-frequency feeding signal from the outside of the SMT-type slot-antenna component with the slot defined in said conductive surface (111).

56. The SMT-type slot-antenna component according to any of claims 52 to 55, further comprising at least one, two, three, four or more further grounding terminals (115a - 115e).

57. The SMT-type slot-antenna component according to any of claims 52 to 56, further comprising at least one, two, three, four or more further feeding terminals (104).

58. The SMT-type slot-antenna component according to any of claims 52 to 57, wherein at least one, two, three or more grounding terminals (1144a, 144b) are arranged such that they are also suitable for feeding a radio-frequency feeding signal from the outside of the SMT-type slot-antenna component with the slot defined in said conductive surface.

59. The SMT-type slot-antenna component according to any of claims 52 to 58, wherein at least one, two, three, four or more grounding terminals (145)/feeding terminals (114, 164) are arranged such that they can only be used as grounding/feeding terminals.

60. The SMT-type slot-antenna component according to any of claims 52 to 59, further comprising one, two, three or more electronic elements or circuits, which preferably are arranged such that they are not in the projection of the slot contained in the SMT-type slot-antenna component.

61. The SMT-type slot-antenna component according to any of claims 52 to 60, comprising more than one, two or three conductive surfaces (191, 192), in which a slot or one, two, three or more portion (193)/portions (194, 195) of a slot are provided.

62. The SMT-type slot-antenna component according to any of claims 52 to 61, wherein two conductive surfaces are provided on the two opposite sides of the dielectric substrate.

63. The SMT-type slot-antenna component according to any of claims 61 or 62, wherein at least two conductive surfaces are electrically connected for example with via holes (196, 197) or are not electrically connected.

64. The SMT-type slot-antenna component according to any of claims 52 to 63, wherein the conductive surface is covered by a dielectric layer such as for example ink or a layer of protective epoxy coating, in which preferably one, two, three or more windows are left, in order to create one, two, three or more contact terminals.

65. The SMT-type slot-antenna component according to any of claims 52 to 64, wherein the slot is open at none, one or two ends and is closed at the remaining ends.

66. The SMT-type slot-antenna component according to any of claims 52 to 65, wherein grounding terminals (115a - 115d) are located close to at least two opposite edges of the slot-antenna component, preferably those two edges that are farthest apart from each other.

67. The SMT-type slot-antenna component according to claim 66, wherein grounding terminals (115a - 115d) are located close to at least two corners of said at least two opposite edges, preferably at the four corners of said two opposite edges.

68. The SMT-type slot-antenna component according to any of claims 52 to 67, wherein at least one, two, three or four grounding terminals (145) extend along an edge of the component or the conductive surface or at least along 40%, 50%, 60%, 70%, 80%, 90% or 95 % of said edge.

69. The SMT-type slot-antenna component according to any of claims 52 to 68, wherein grounding terminals (115a, 115e, 165a, 165b) are placed at two sides of a feeding terminal (114, 164) and preferably substantially close to said feeding terminal (114, 164).

70. The SMT-type slot-antenna component according to any of claims 52 to 69, wherein feeding terminals (144a, 144b) are provided on two sides of the slot (143).

71. The SMT-type slot-antenna component according to any of claims 52 to 70, wherein a conductive strip (118, 168) is connecting the edge of the slot (113, 163) farther away from the feeding terminal (114, 164).

72. The SMT-type slot-antenna component according to claim 71, wherein said conductive strip (118, 168) and the conductive surface (111, 161) are coplanar.

73. The SMT-type slot-antenna component according to any of claims 52 to 72, wherein a clearance region (120, 170) is provided at least on two sides of a feeding terminal (114, 164).

74. The SMT-type slot-antenna component according to any of claims 71 to 73, wherein the width (d1, d2) of the clearance region of the feeding terminal (114, 164) and/or the width of the conductive strip (118, 168) is smaller than a maximum value of the group comprising: 1/2400, 1/1200, 1/800, 1/600 1/480, 1/400, 1/300, 1/240, 1/200, 1/150 and 1/120 of a free space operating wavelength of the slot antenna.

75. The SMT-type slot-antenna component according to any of claims 71 to 74, wherein a clearance region (120, 170) is provided at both sides of the conductive strip (118, 168).

76. The SMT-type slot-antenna component according to any of claims 71 to 75, wherein the feeding terminal (114, 164) is coupled to the conductive strip (118, 168) by conductive coupling such as by a direct electric connection, a via hole, by capacitive coupling or inductive coupling.

77. A wireless device such as a handheld or portable device comprising a circuit board (121) such as a printed circuit board and an SMT-type slot-antenna component of any of claims 52 to 76 wherein the circuit board (121) comprises a ground plane (131).

78. The wireless device according to claim 77, wherein the ground plane (131) of the circuit board has a clearance (132) at least in a part of the orthogonal projection (150) of the SMT-type slot-antenna component onto the circuit board on which the component is mounted.

79. The wireless device according to claim 77 or 78, wherein the ground plane (131) of the circuit board is provided in a portion of the orthogonal projection of the SMT-type slot antenna component onto the circuit board on which the component is mounted, but not in the orthogonal projection of the slot of the conductive surface of the SMT-type slot-antenna component on the circuit board.

80. The wireless device according to claim 77 or 78, wherein the ground plane (131) of the circuit board (121) is provided in a portion of the orthogonal projection of the SMT-type slot antenna component onto the circuit board on which the component is mounted, and also in a fraction of the projection of the slot wherein the fraction is less or equal to a value of the group comprising 50%, 40%, 30%, 25%, 20%, 15%, 10% and 5%.

81. The wireless device according to any of claims 77 to 80, wherein one, two, three, four, five or more protrusions (135) of the ground plane (131) of the circuit board extend into the clearance (132).

82. The wireless device according to any of claims 77 to 81, wherein the size of the clearance (132) of the ground plane of the circuit board is smaller than the size of the SMT-type slot-antenna component or smaller than 90%, 80%, 70%, 60%, 50%, 40%, 30% or 20% of the size of the SMT-type slot-antenna component and /or larger than 10%, 20%, 30%, 40%, 50%, 60%, 70% 80%, 90% of the size of the SMT-type slot-antenna component .

83. The wireless device according to any of claims 77 to 82, wherein one, two, three or more portions (153) of the antenna slot is provided in the ground plane (121) of the circuit board, wherein one, two, three or more slots (153) of the ground plane

(121) and the slot (143) of the SMT-type slot-antenna component (150) are preferably connected.

84. The wireless device according to any of claims 77 to 83, wherein an edge preferably a long edge of the SMT-type slot-antenna component (150) is oriented along a long or short edge of the circuit board.

85. The wireless device according to any of claims 77 to 84, wherein the SMT-type slot-antenna component (150) is provided not farther away from an edge of the circuit board (151) by more than the extension of the component (150) in the direction perpendicular to the edge of the circuit board or not farther away than 80%, 60%, 40%, or 20% of said extension.

86. The wireless device according to any of claims 77 to 85, wherein the SMT-type slot-antenna component is provided at the middle (74) of an edge (73) of the ground plane of the circuit board or not farther away from a middle than the extension of the component along the edge or not farther away than 80%, 60%, 40%, or 20% of said extension.

87. The wireless device according to any of claims 77 to 86, wherein the slot is contacted for balanced or unbalanced feeding.

88. The wireless device according to any of claims 77 to 87, wherein a coplanar transmission line (181), a coaxial transmission line (184) or a microstrip transmission line (186) is provided for exciting the slot.

89. The wireless device according to any of claims 77 to 88, wherein two, three, four or more SMT-type slot-antenna components of any of claims 52 to 76 are provided.

90. The wireless device according to claim 89, wherein at least two SMT-type slot-antenna components (211, 212) are arranged substantially orthogonal to each other.

91. The wireless device according to any of claims 77 to 90, wherein at least two slot antennas (211, 212) are provided, none, one or two of them being provided with an SMT-type slot-antenna component of any of claims 52 to 76, wherein the two slot antennas can radiate with orthogonal polarizations.

92. The wireless device according to any of claims 77 to 91, wherein the circuit board (121) comprises a pad (134) which is connected to the feeding terminal (114) of the SMT-type slot-antenna component (110), wherein this pad (134) is or is not connected to the ground plane of the circuit board.

93. The wireless device according to any of claims 77 to 92, wherein the SMT-type slot-antenna component is square with a length L or rectangular with a length L which is the longer dimension of the rectangle, wherein L divided by a free space operating wavelength of the slot antenna is smaller than or approximately equal to a fraction of the group comprising: 1/5, 1/8, 1/10, 1/12, 1/13, 1/14, 1/15, 1/16, 1/18, and 1/20.

94. The wireless device according to any of claims 77 to 93, wherein the SMT-type slot-antenna component is rectangular with a width (W) which is the shorter dimension of the rectangle, wherein the width (W) divided by a free-space operating wavelength of the slot antenna is smaller than or approximately equal to a fraction of the group comprising: 1/10, 1/15, 1/18, 1/20, 1/21, 1/22, 1/23, 1/24, 1/25, and 1/30.

95. The wireless device according to any of claims 77 to 94, wherein the SMT-type slot-antenna component has a height (H), wherein the height (H) divided by a free-space operating wavelength of the slot antenna is smaller than or approximately equal to a fraction of the group comprising: 1/40, 1/60, and 1/120.

96. The wireless device according to any of claims 77 to 95, wherein the SMT-type slot antenna component (150) together with a connected slot portion (153) in the ground plane (151) of the circuit board (121) fits into a rectangular area of width (W') and length (L'), wherein the sum of said length (L') and width (W') divided by a free

space operating wavelength is less than or approximately equal to a percentage of the group comprising 25%, 22.5%, 20%, 17.5%, 15%, 12.5%, and 10%.

97. The wireless device according to any of claims 77 to 96, wherein the unfolded length of the slot-portion (153) in the ground plane (151) of the circuit board (121 divided by the unfolded length of the combination of the slot (143) and said slot portion (153) is less than a percentage of the group comprising 50%, 40%, 30%, 25%, 20%, 18%, 16%, 14%, 12%, 10% and 5%.

98. The wireless device according to any of claims 77 to 97, wherein the separation between two edges of a slot (113, 143) and/or a slot portion (153) in the ground plane (131, 151) of the circuit board (121) divided by a free space operating wavelength is less than a percentage of the group comprising 8 %, 4%, 2%, 1%, and 0.5%, and/or more than a percentage of the group comprising 0.08%, 0.12%, 0.16%, 0.20%, and 0.24%.

99. The wireless device according to any of claims 77 to 98, wherein the slot (143) of the SMT-type slot-antenna component (150) in combination with a slot portion (153) in the ground plane (151) of the circuit board (121) is open at none, one or two ends (146) and closed at the other ends.

100. The wireless device according to any of claims 77 to 99, wherein for exciting the slot region (158) a coplanar transmission line (181), a coaxial transmission line (184) or a microstrip transmission line (186) is provided.

101. The wireless device according to any of claims 77 to 100, wherein the slot antenna is closed at one end and the slot or slot section can be excited by applying a voltage difference between opposite conductive edges of the slot or slot section at a certain point along the geometry of the slot, wherein said point is closer to the closed end along the geometry of the slot than to the other end and/or the distance between said point and said closed end divided by a free space operating wavelength is less than or equal to a value of the group comprising: 0.002, 0.004, 0.008, 0.012, 0.016, 0.025, 0.033, 0.04, 0.08, 0.1 and 0.15.

102. The wireless device according to any of claims 77 to 101, wherein the SMT-type slot-antenna component (211) of any of claims 52 to 76 has a longer dimension which is substantially perpendicular to a longer dimension of a second SMT-type slot-antenna component (212) of any of claims 52 to 76.

103. The wireless device according to any of claims 77 to 102, wherein the SMT-type slot-antenna component (211) of any of claims 52 to 76 and a second SMT-type slot-antenna component (212) of any of claims 52 to 76 form or form part of an antenna diversity system.

104. The wireless device according to any of claims 77 to 103, wherein at least a portion of a curve defining the slot or a slot section is a space filling curve, a box counting curve, a grid-dimension curve or a fractal based curve.

105. The wireless device according to any of claims 77 to 104, wherein a curve defining the slot or the slot section branches out in two or more curves, which preferably are space filling, box-counting, grid-dimension or fractal based curves.

106. The wireless device according to any of claims 77 to 105, wherein the slot of the slot antenna is formed like a polygonal or multilevel surface or coupled through direct contact or electromagnetic coupling to a conducting polygonal or multilevel surface or polygonal or multilevel shaped slot.

107. The wireless device according to any of claims 77 to 106, wherein the wireless device is at least one or a combination of wireless devices of a group of wireless devices comprising: a cellular phone, a mobile phone, a handheld phone, a smart phone, a satellite phone, a multimedia terminal, personal digital assistant (PDA), a portable music player, a radio, a digital camera, a USB dongle, a wireless headset, an ear phone, a hands-free kit, an electronic game, a remote control, an electric switch, a light switch, an alarm, a car kit, a computer card, a PCMCIA card, a sensor, a headset, a dongle, a computer interface a computer mouse, a keyboard, a personal computer, a MP3 player, a portable DVD/CD player, a smoke detector, a

switch, a motion sensor, a pressure sensor, a temperature sensor, a medical sensor, a meter, a short/medium range wireless connectivity application, a Mini-PCI, a Notebook, PC with WiFi module integrated, a compact flash wireless card, a UART dongle, a pocket PC with integrated Wi-Fi, an access point for a hot spot, a wireless wrist watch, a wireless wrist sensor, a bracelet FM radio, an MP3 player, a radio frequency identification tag, key remote entry system, an air pressure sensor e.g. in a tire, a radio controlled toy, a laptop and a cardbus 32 card.

108. The wireless device according to any of claims 77 to 107, wherein the wireless device is configured for operation in one, two, three or more of the wireless communication systems preferably selected from the group comprising: Bluetooth, 2.4GHz Bluetooth, 2.4 GHz WiMAX, ZigBee, ZigBee at 860 MHz, ZigBee at 915 MHz, GPS, GPS at 1.575 GHz, GPS at 1.227 GHz, Galileo, GSM 450, GSM 850, GSM 900, GSM 1800, American GSM, DCS-1800, UMTS, CDMA, DMB, DVB-H, WLAN, WLAN at 2.4 GHz-6GHz, PCS 1900, KPCS, WCDMA, SDARs, XDARS, DAB, WiFi, UWB, 2.4-2.483 GHz band, 2.471-2.497 GHz band, IEEE802.11ba, IEEE802.11b, IEEE802.11g and FM.

109. A wireless device such as a handheld or portable device comprising a circuit board (121) such as a printed circuit board and a slot-antenna component (110), wherein said circuit board (121) comprises a ground plane, and wherein said slot-antenna component comprises:

- at least one conductive surface (111), different from the ground plane of the circuit board (121), on which a pattern of a slot (113) is created;
- a dielectric substrate (112) that backs said at least one conductive surface (111), or in which said at least one conducting surface (111) is embedded;
- at least one contact terminal (115a, 115b) named grounding terminal accessible from the exterior of said slot-antenna component (110) to electrically connect said at least one conductive surface (111) included in the slot-antenna component with the ground plane of the circuit board (121);
- and at least one contact terminal (114) named feeding terminal to couple a radio-frequency feeding signal from the outside of the slot-antenna

component (110) with the slot (113) defined in said at least one conductive surface (111);

wherein said slot-antenna component (110) has a rectangular shape with a length (L) smaller than 1/10 of a free-space operating wavelength of the slot antenna, a width (W) smaller than 1/15 of a free-space operating wavelength of the slot antenna and a height (H) smaller than 1/60 of a free-space operating wavelength of the slot antenna;

wherein the unfolded length of the slot antenna comprising the slot (113) created in said at least one conductive surface (111) of the slot-antenna component is approximately a quarter of an operating wavelength of the slot antenna;

wherein at least a portion of the slot (113) created in said at least one conductive surface of the slot-antenna component is shaped as a space-filling curve, or a box-counting curve, or a grid dimension curve;

wherein the slot-antenna component (110) comprises a second grounding terminal (115c, 115d); wherein the first and second grounding terminals (115a, 155b, 115c, 155d) are close to two opposite edges of said slot-antenna component (110);

wherein the slot-antenna component (110) comprises feeding means including a conductive strip (118) connected to the at least one feeding terminal (114), and having a width smaller than 1/300 of a free-space operating wavelength of the slot antenna;

wherein said conductive strip (118) is connected to an edge of the slot (113) created in the at least one conductive surface (111) of the slot-antenna component (110) at a distance from a closed end (117) of said slot (113) smaller than 8% of a free-space operating wavelength of the slot antenna;

and wherein the wireless device is operating at one, two, three or more communication and connectivity services selected from the group comprising GSM850, GSM900, GSM1800, American GSM, PCS1900, GSM450, UMTS, WCDMA, CDMA, Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DMB, and DVB-H.

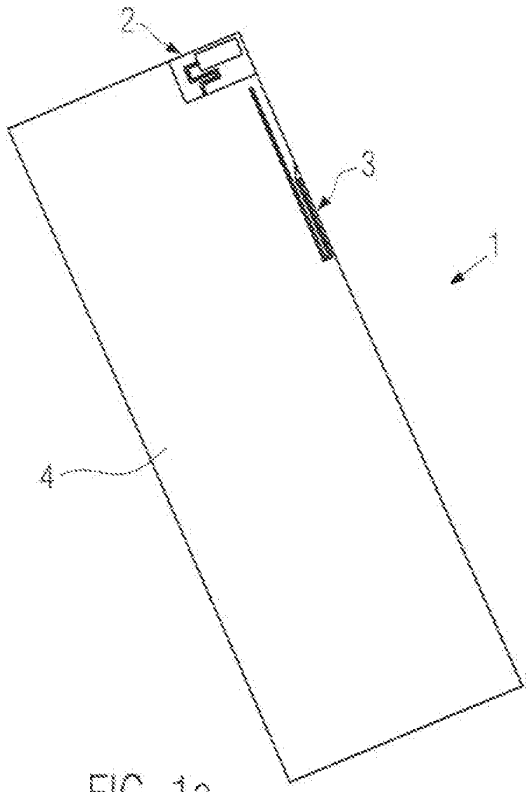


FIG. 1a

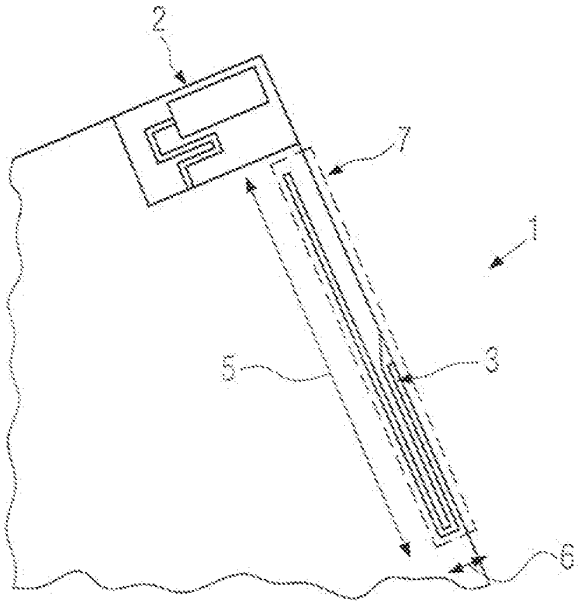


FIG. 1b

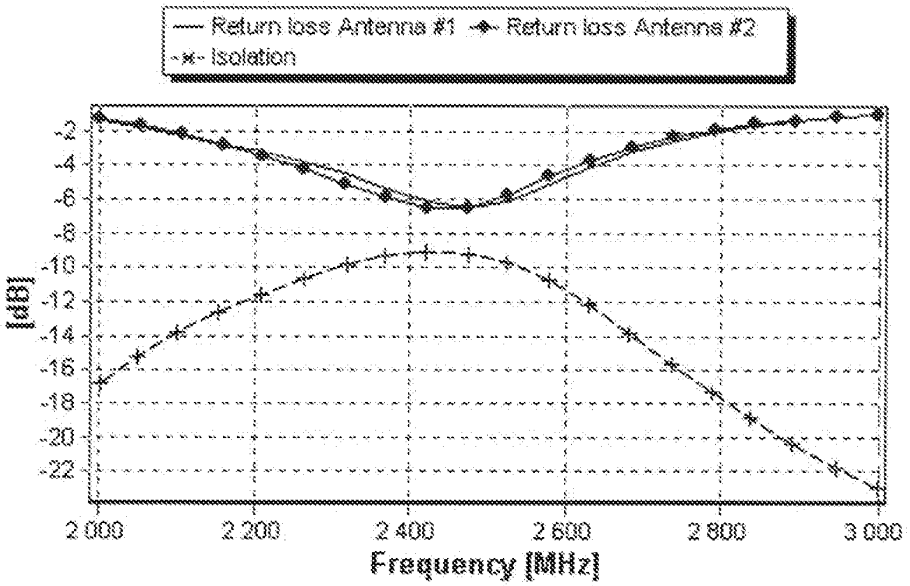

Return loss Antenna #1
Return loss Antenna #2
Isolation
[dB]
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
2 000
2 200
2 400
2 600
2 800
3 000
Frequency [MHz]

FIG. 2a

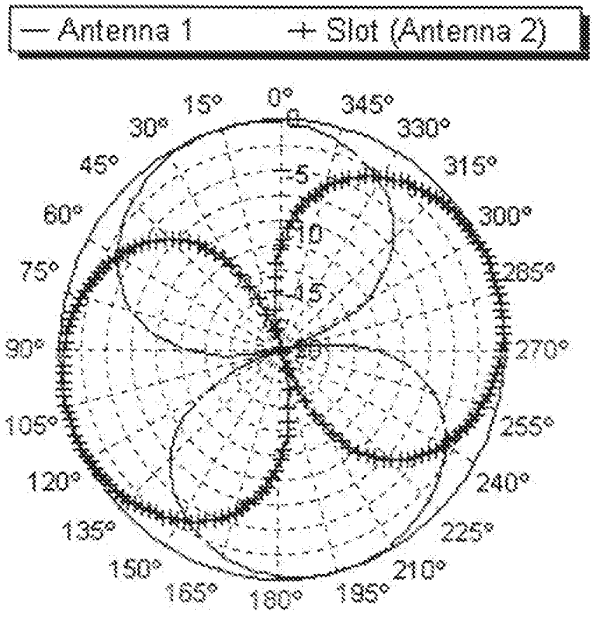

Antenna 1
Slot (Antenna 2)
0°
15°
30°
45°
60°
75°
90°
105°
120°
135°
150°
165°
180°
195°
210°
225°
240°
255°
270°
285°
300°
315°
330°
345°
-5
-10
-15
-20

FIG. 2b

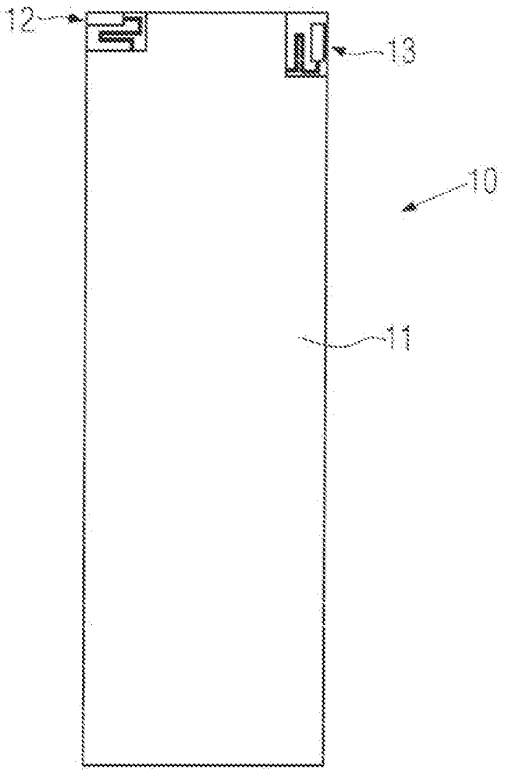


FIG. 3a

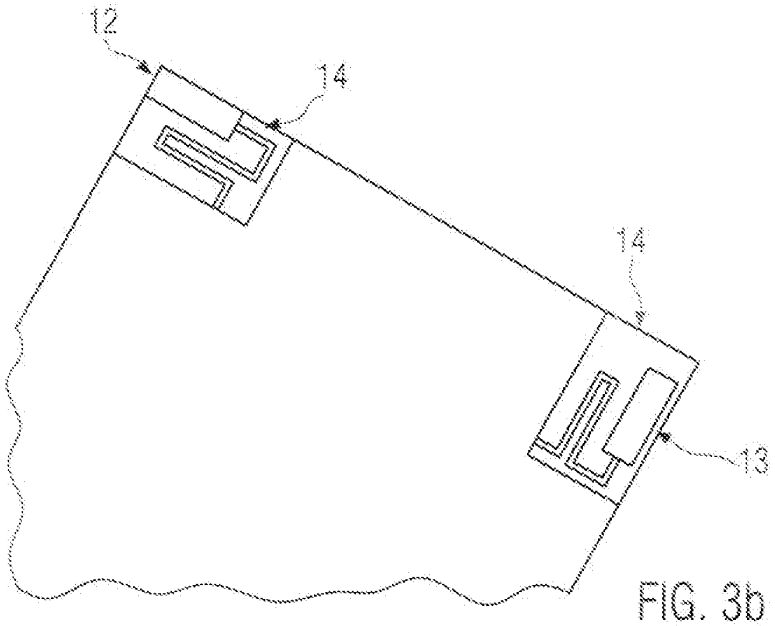


FIG. 3b

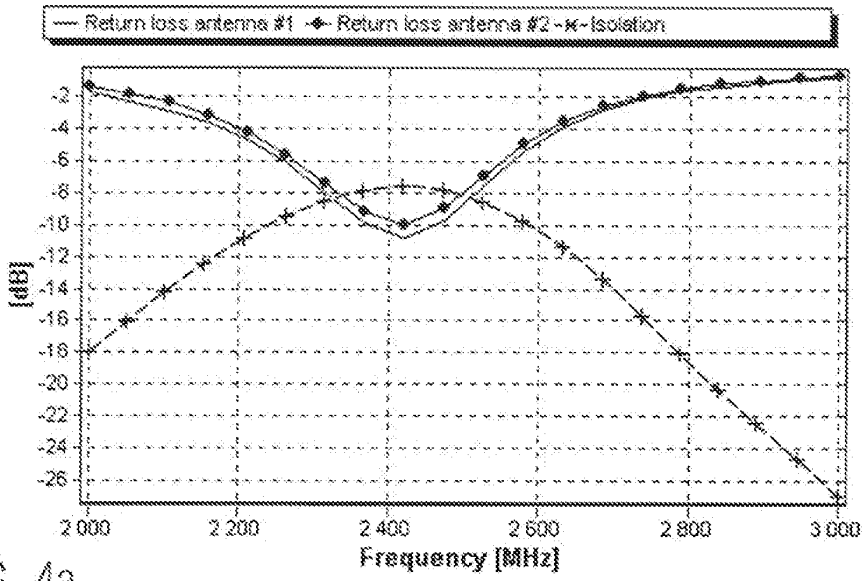

Return loss antenna #1
Return loss antenna #2
Isolation
[dB]
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
2 000
2 200
2 400
2 600
2 800
3 000
Frequency [MHz]

FIG. 4a

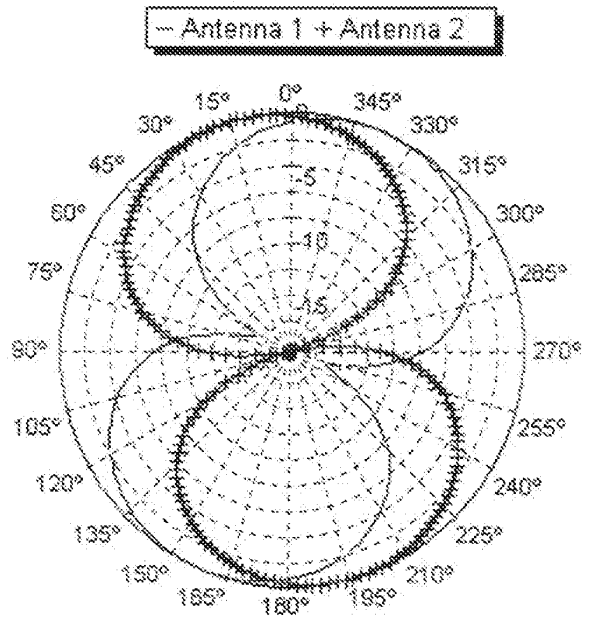

Antenna 1
Antenna 2
0°
15°
30°
45°
60°
75°
90°
105°
120°
135°
150°
165°
180°
195°
210°
225°
240°
255°
270°
285°
300°
315°
330°
345°
-5
-10
-15

FIG. 4b

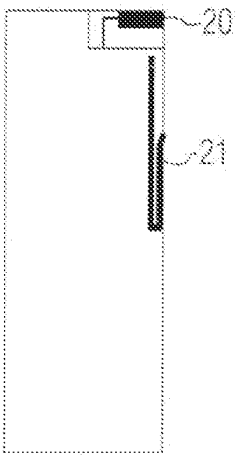


FIG. 5a

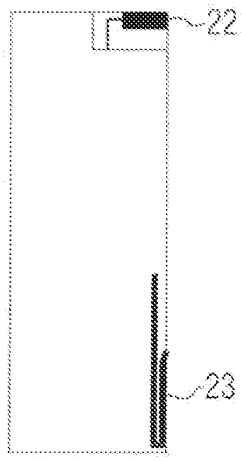


FIG. 5b

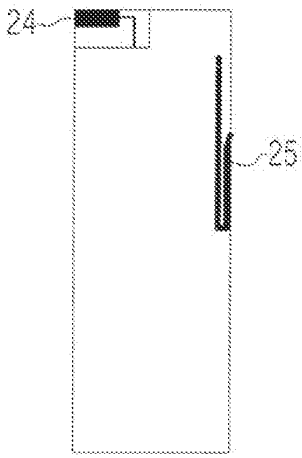


FIG. 5c

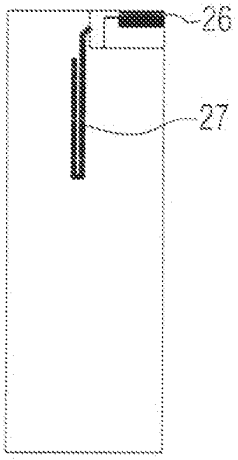


FIG. 5d

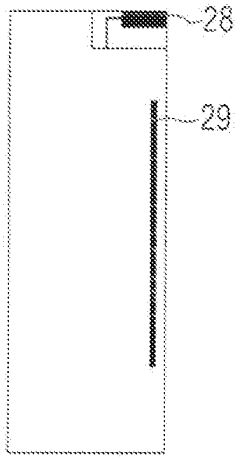


FIG. 5e

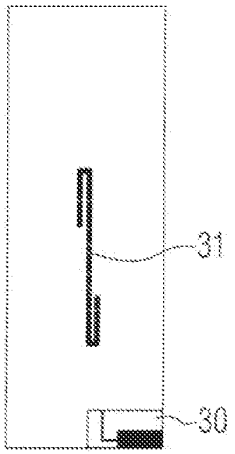


FIG. 5f

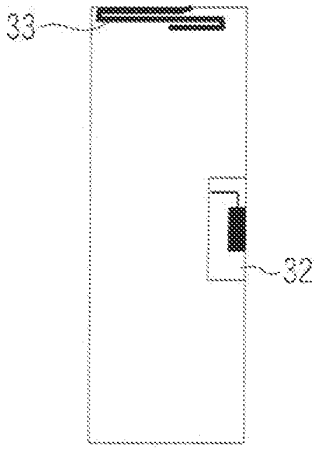


FIG. 5g

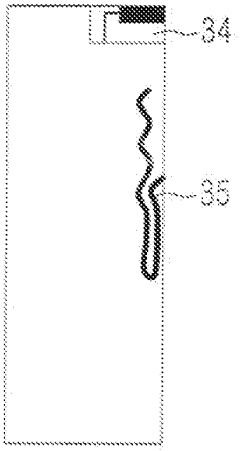


FIG. 5h

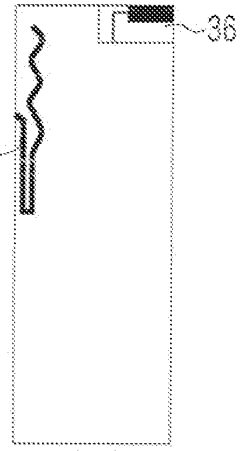


FIG. 5i

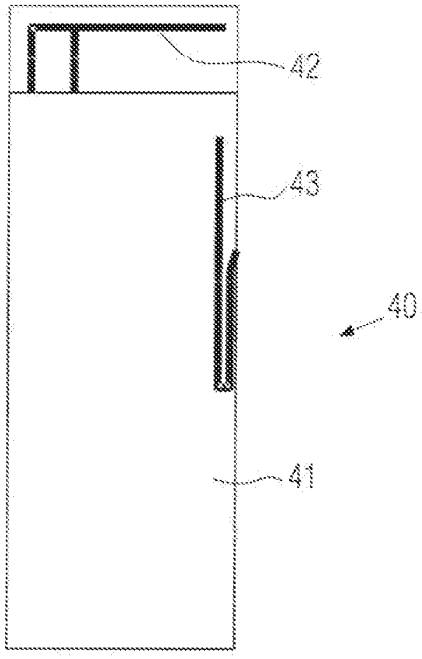


FIG. 6

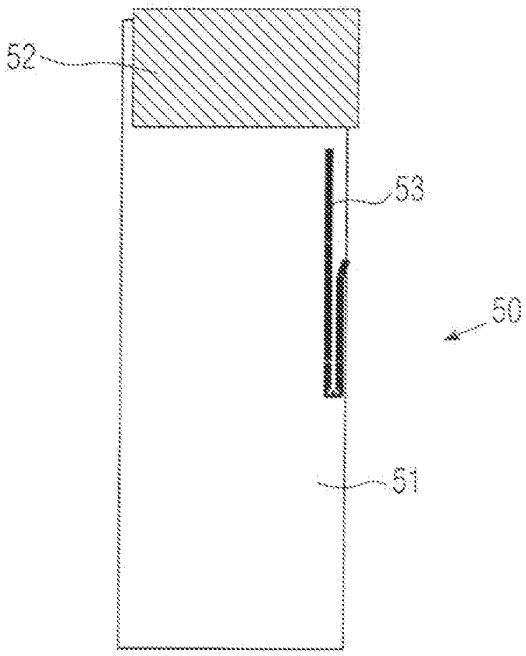


FIG. 7

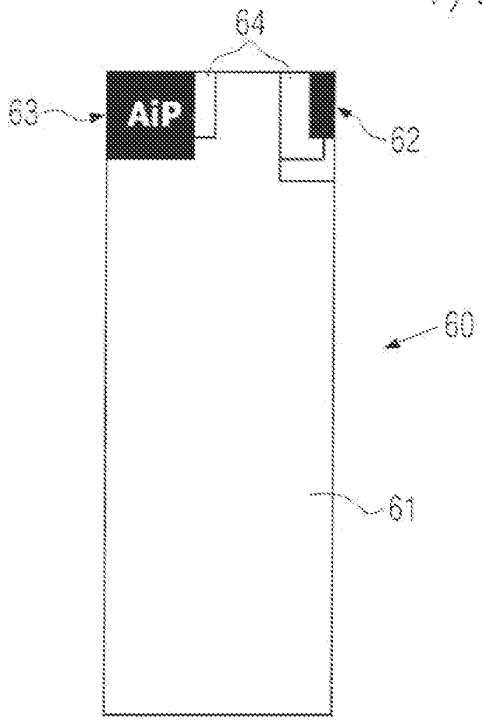


FIG. 8a

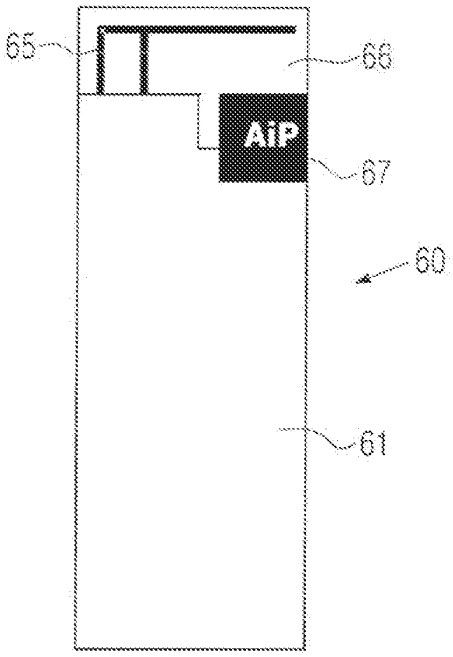


FIG. 8b

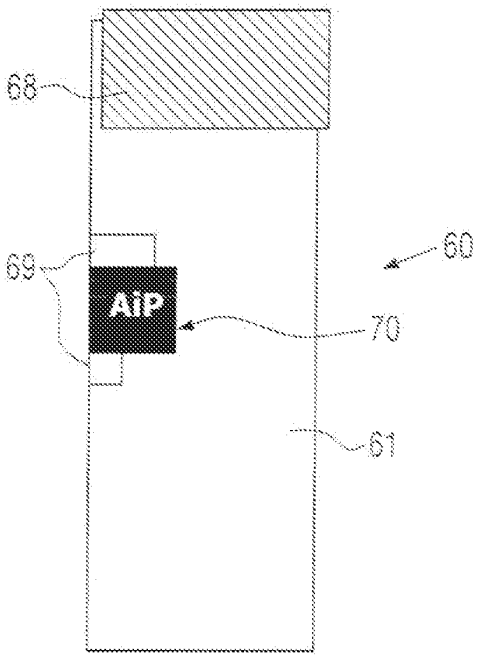


FIG. 8c

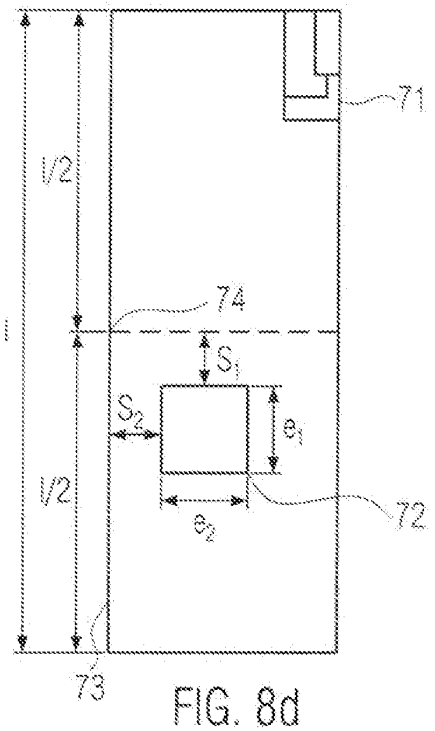


FIG. 8d

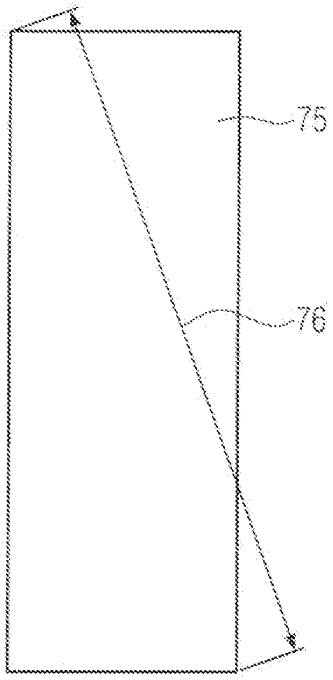


FIG. 8e

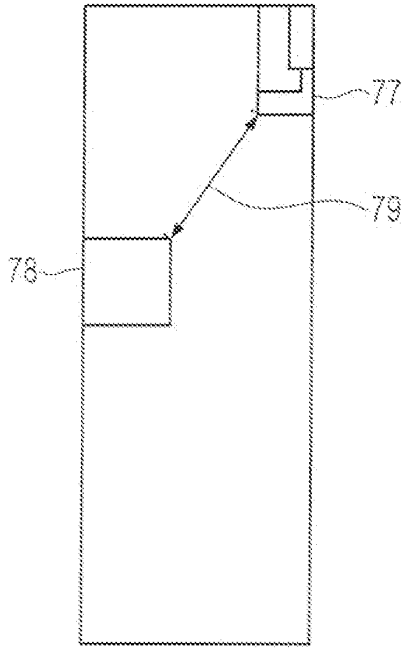


FIG. 8f

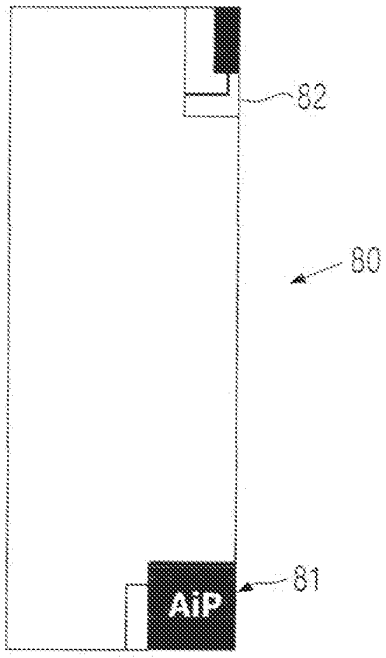


FIG. 9a

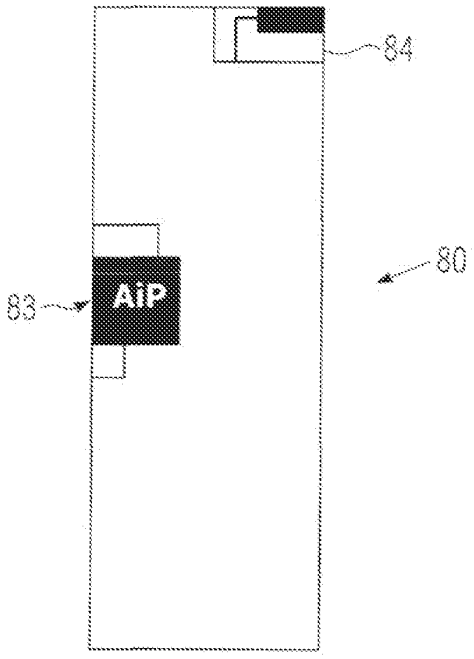


FIG. 9b

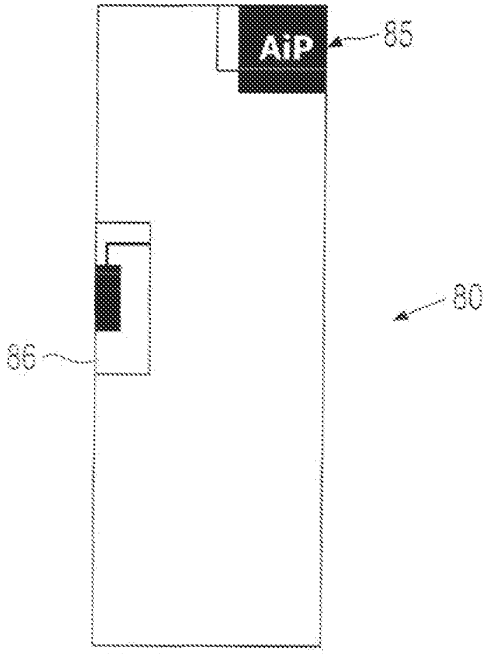


FIG. 9c

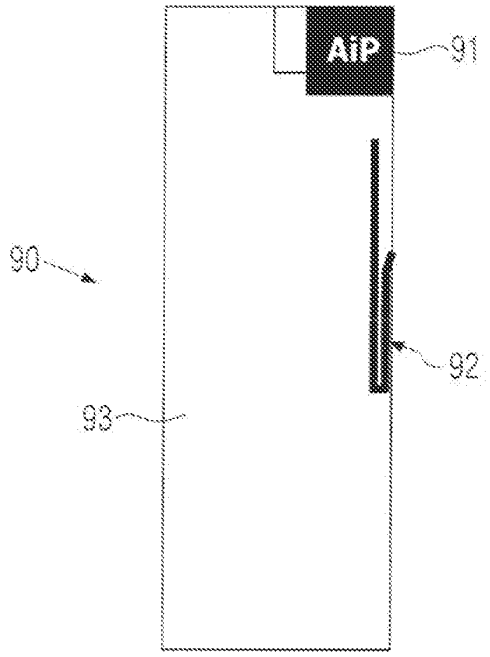


FIG. 10

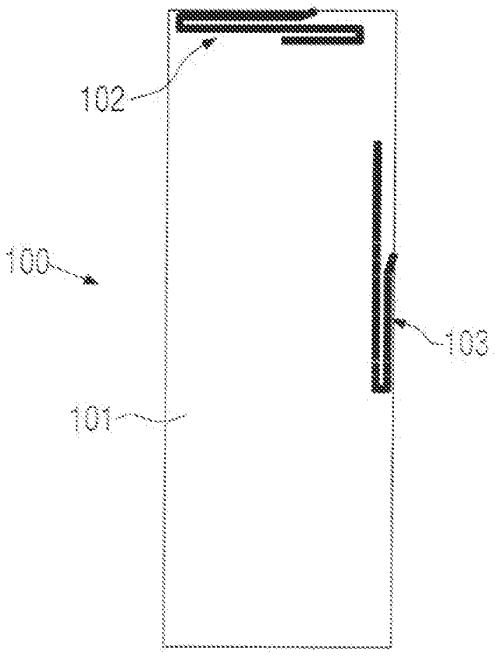


FIG. 11

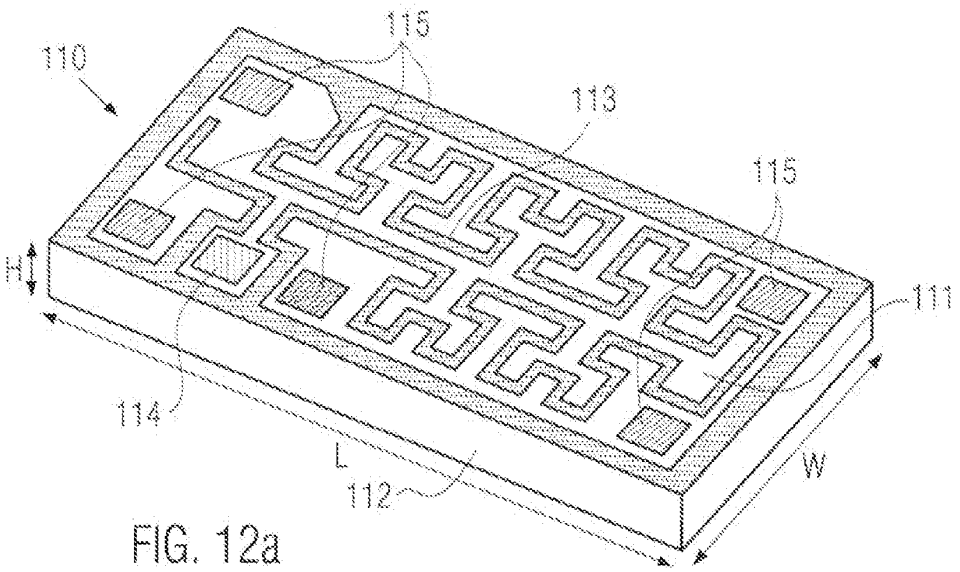


FIG. 12a

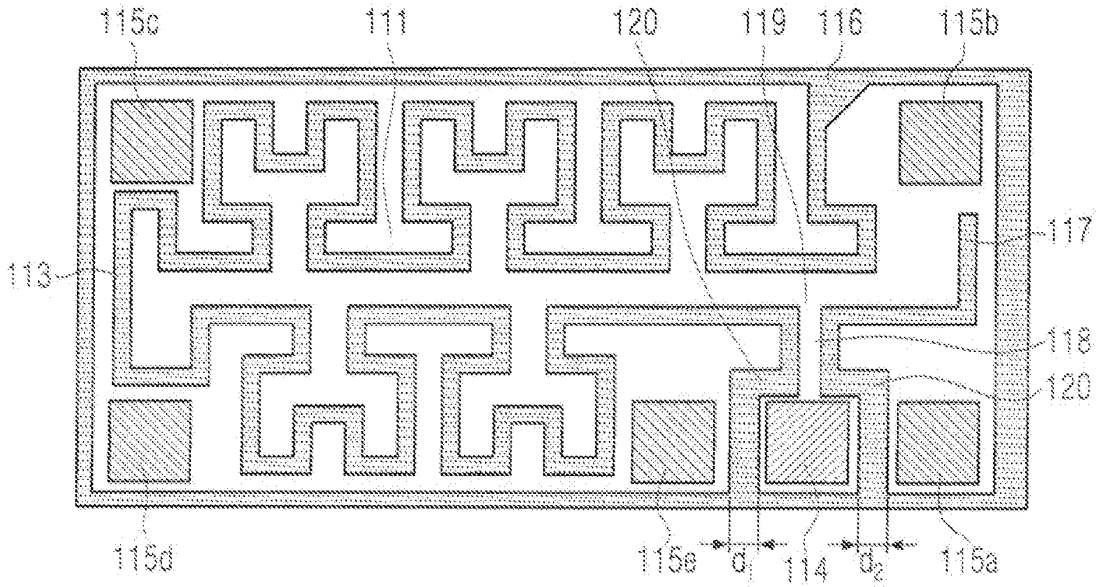


FIG. 12b

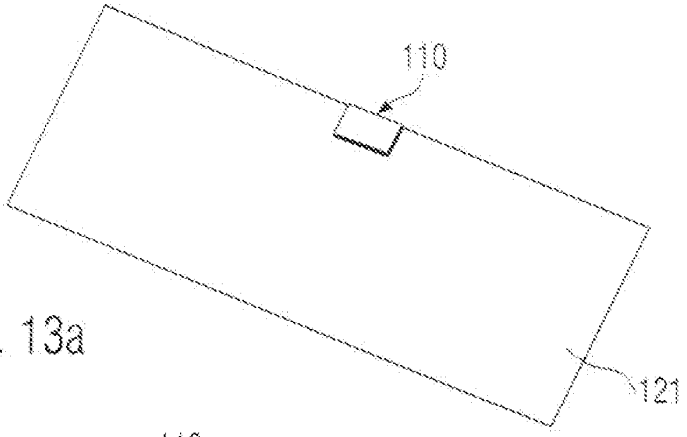


FIG. 13a

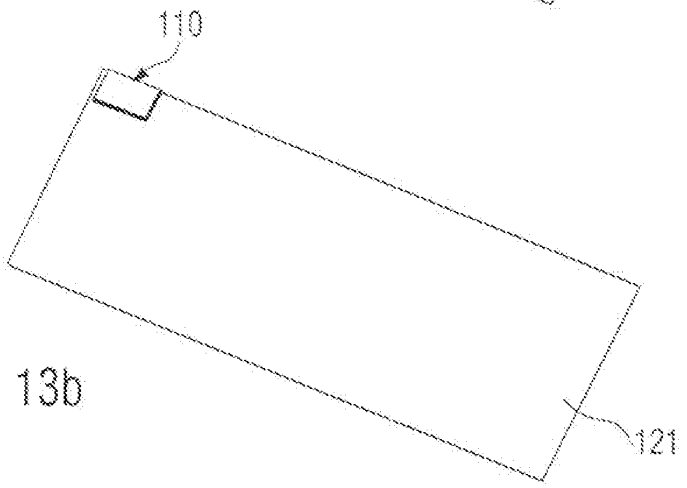


FIG. 13b

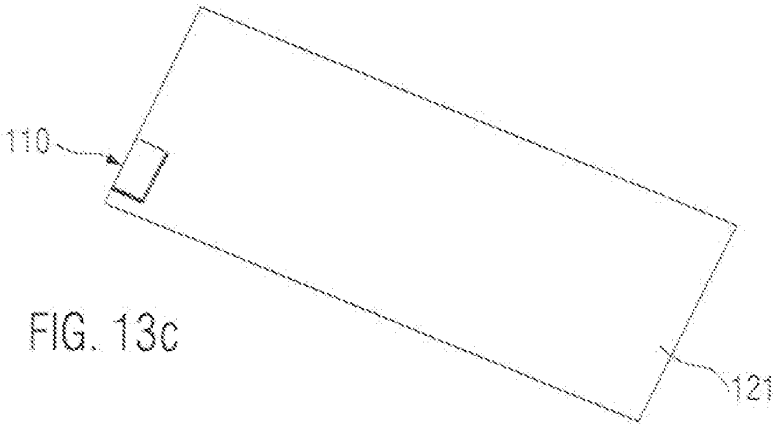


FIG. 13c

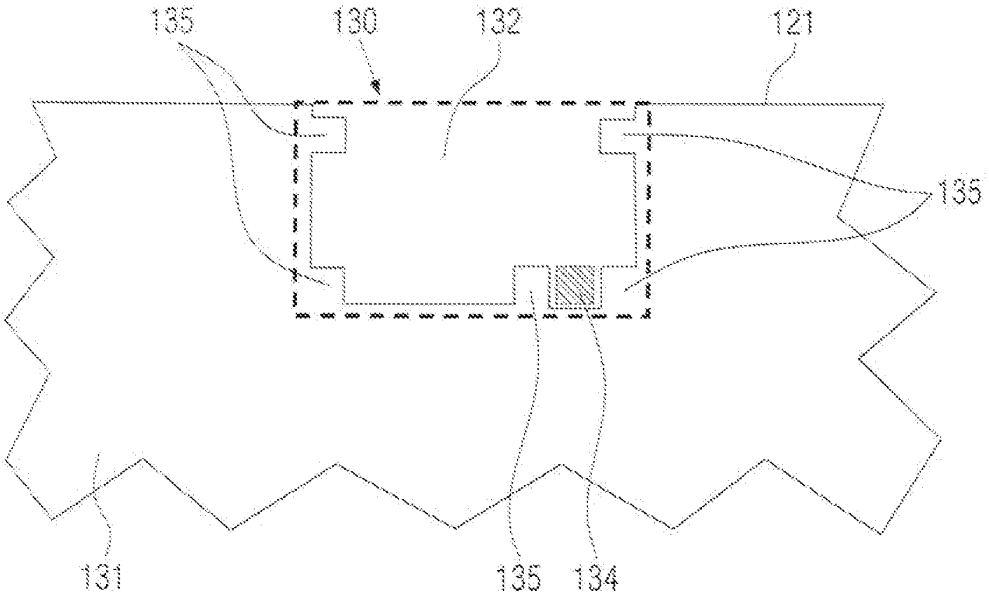


FIG. 14

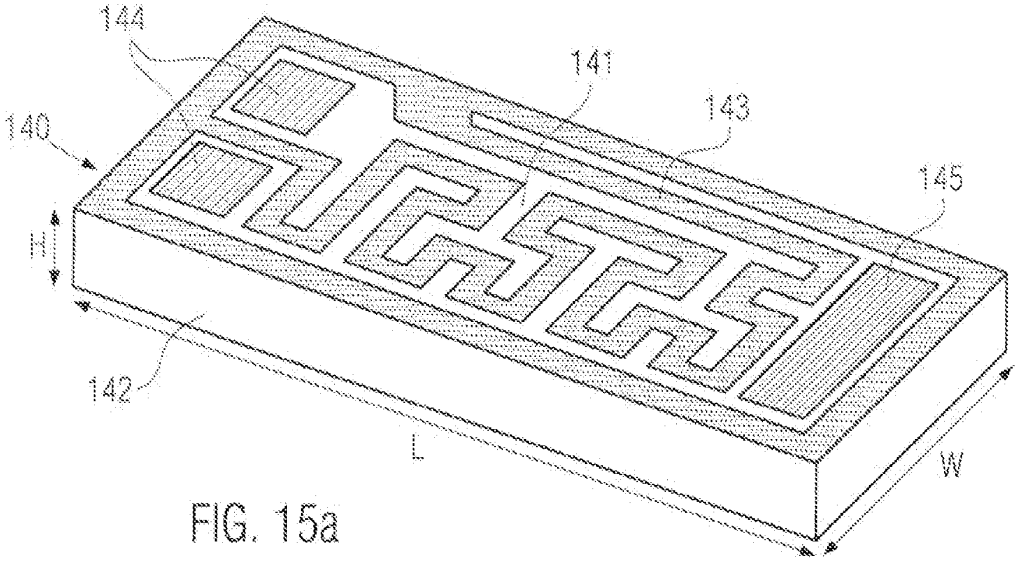


FIG. 15a

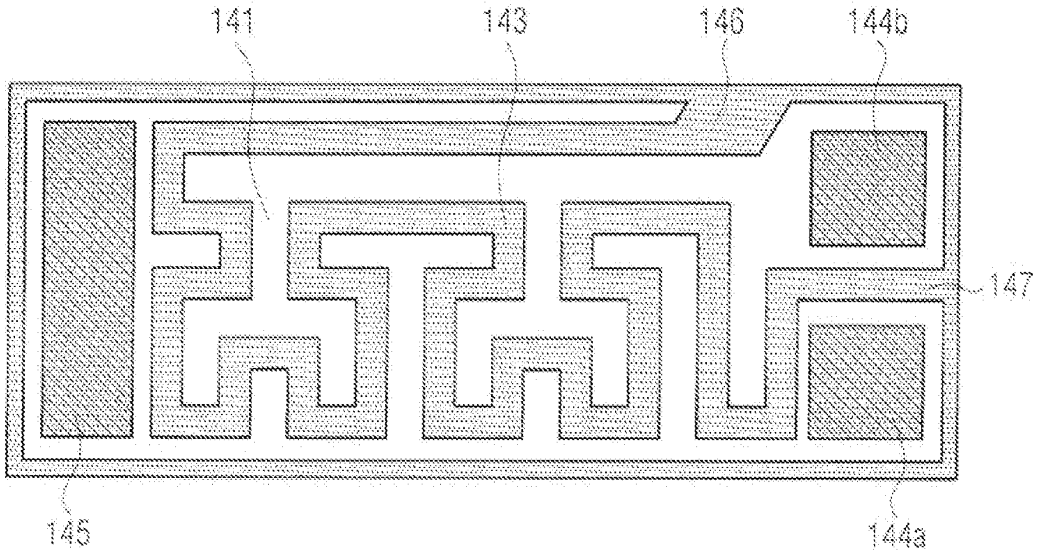


FIG. 15b

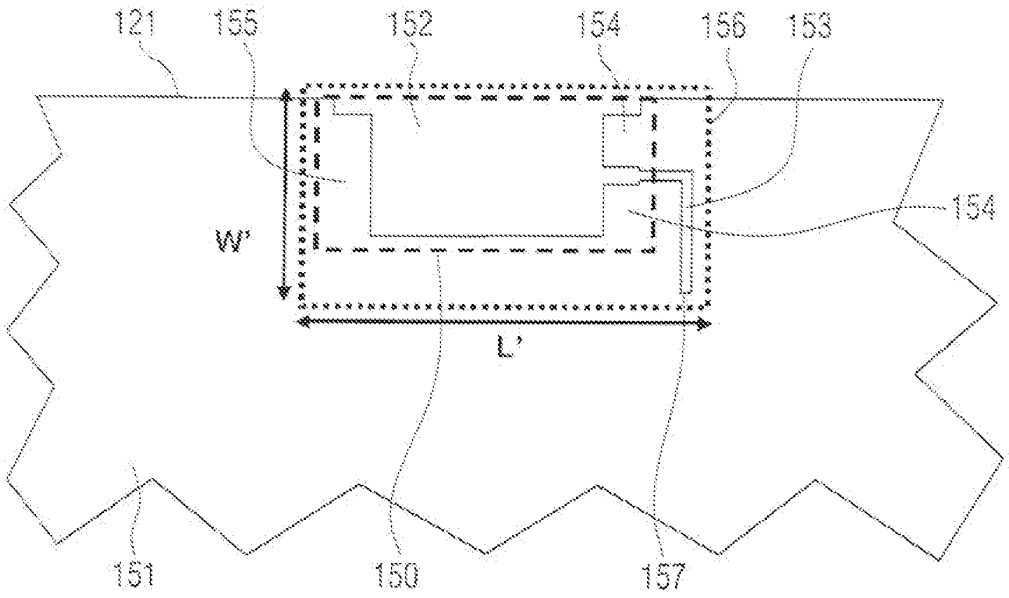


FIG. 16a

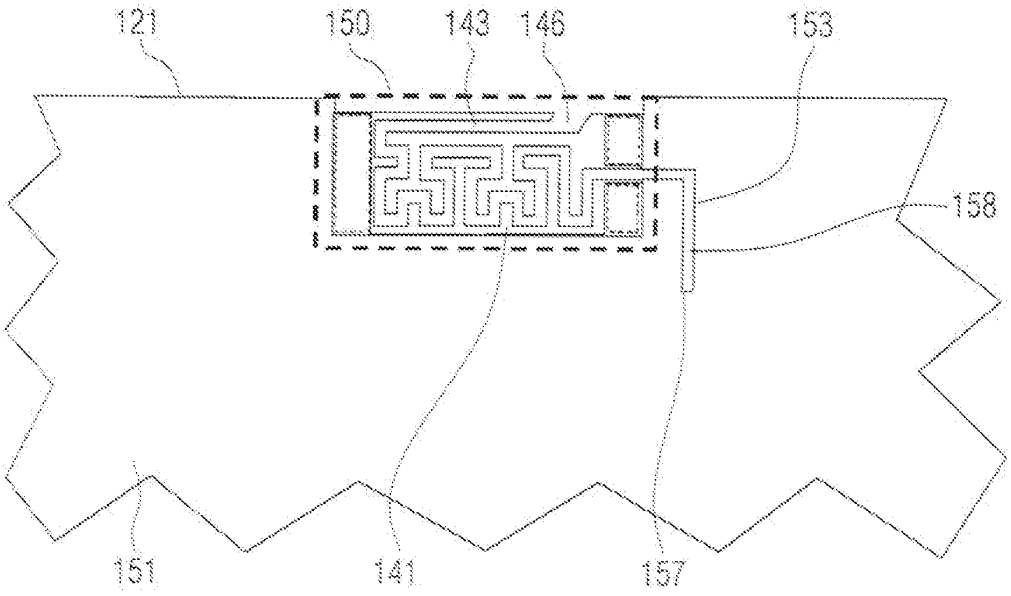


FIG. 16b

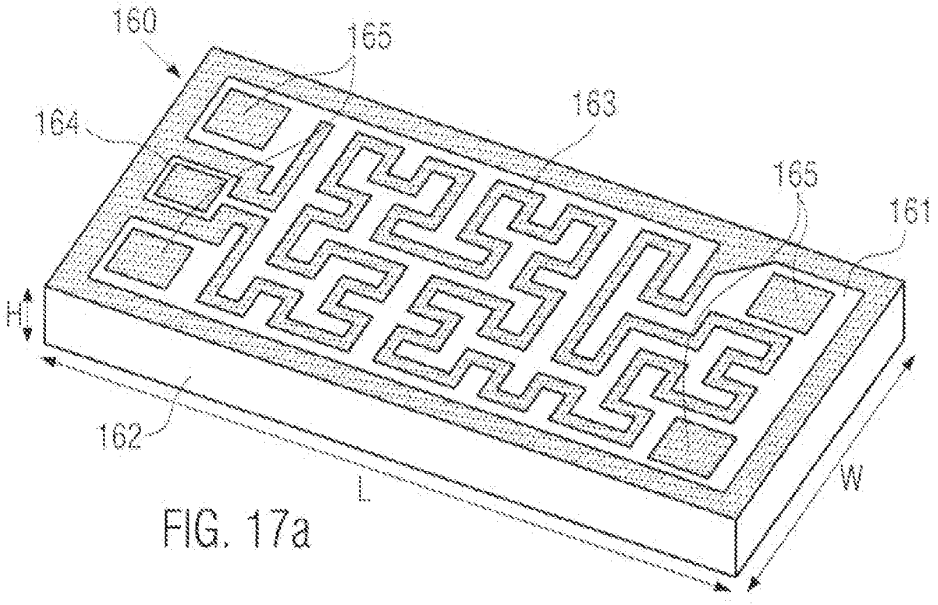


FIG. 17a

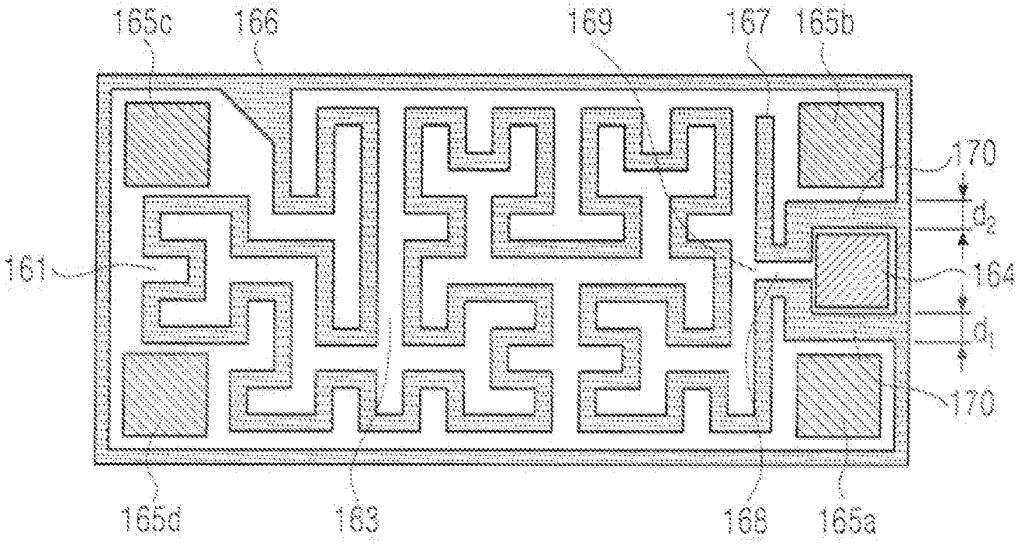


FIG. 17b

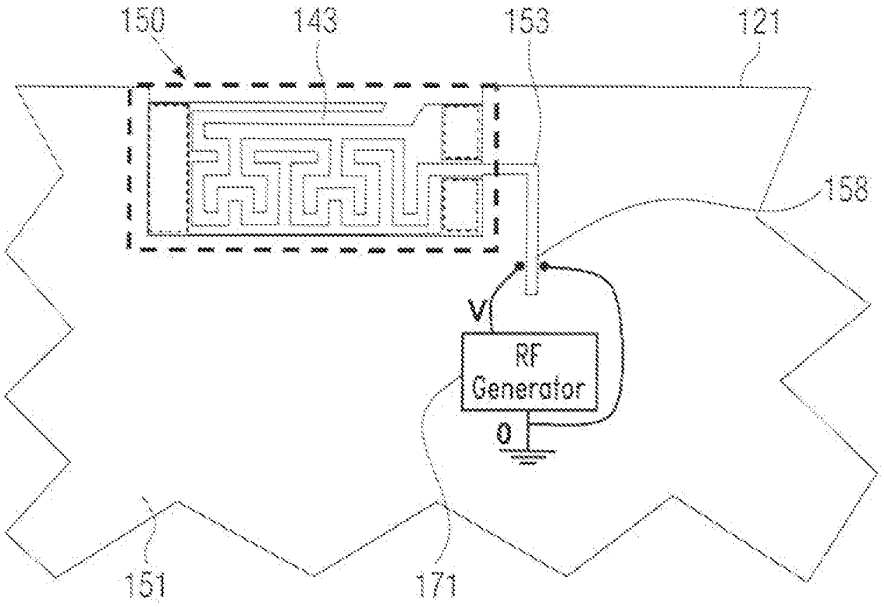


FIG. 18a

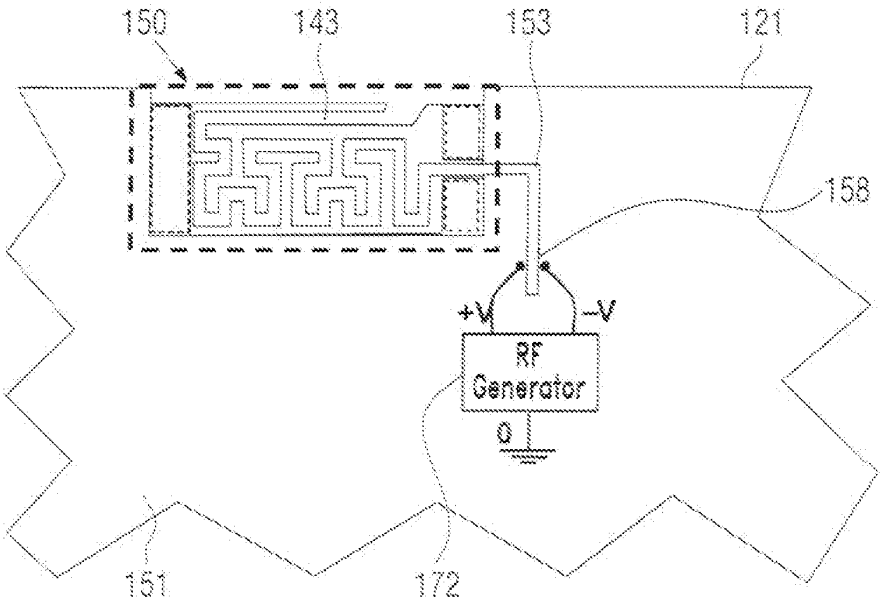


FIG. 18b

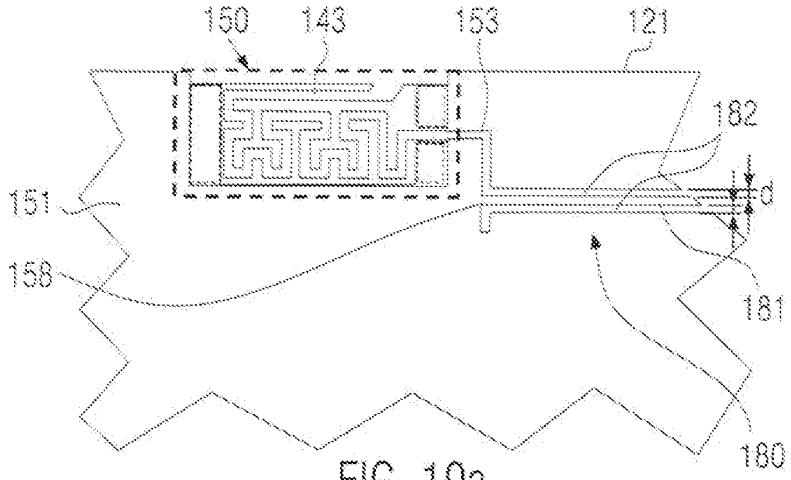


FIG. 19a

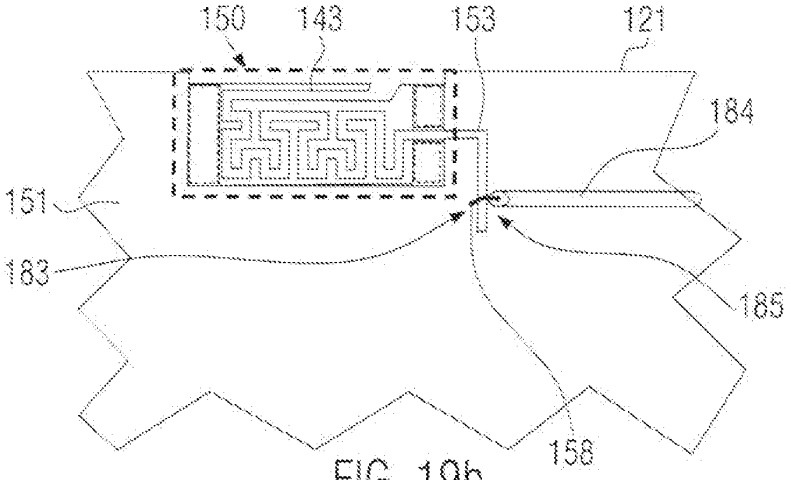


FIG. 19b

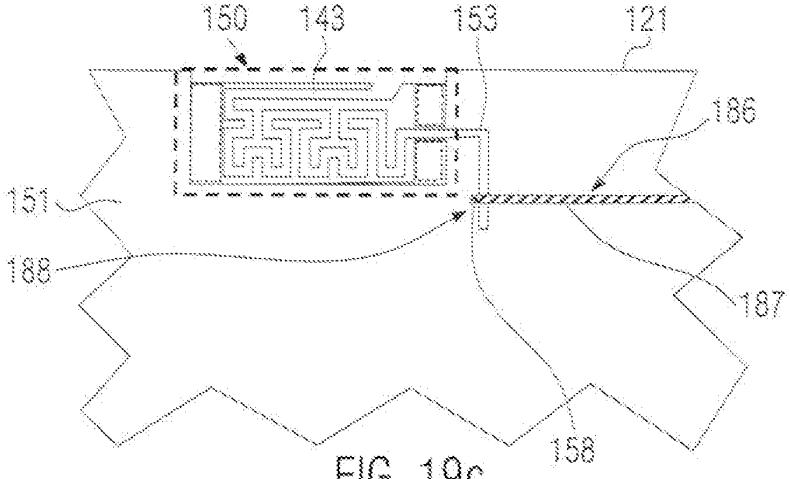


FIG. 19c

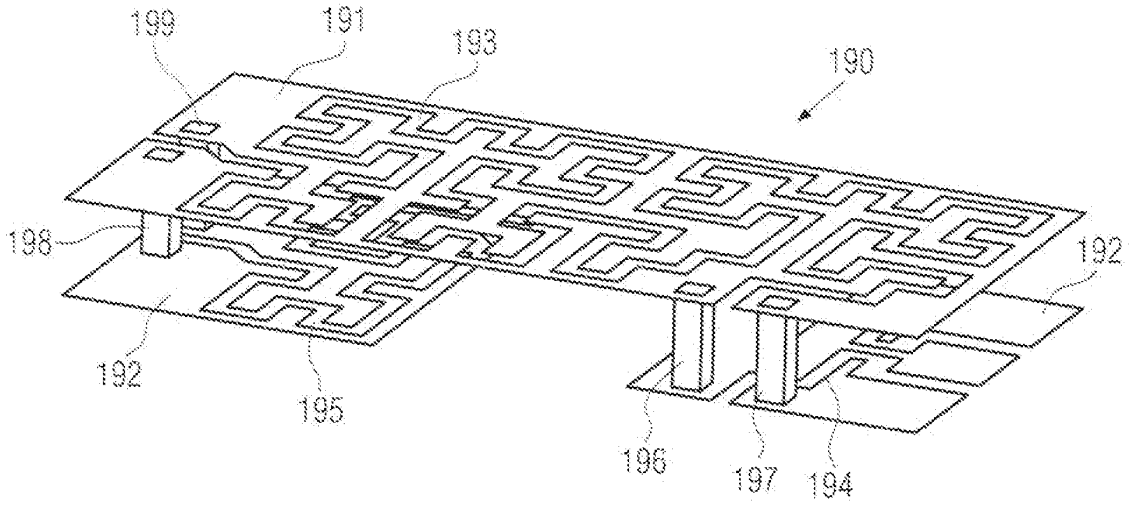


FIG. 20a

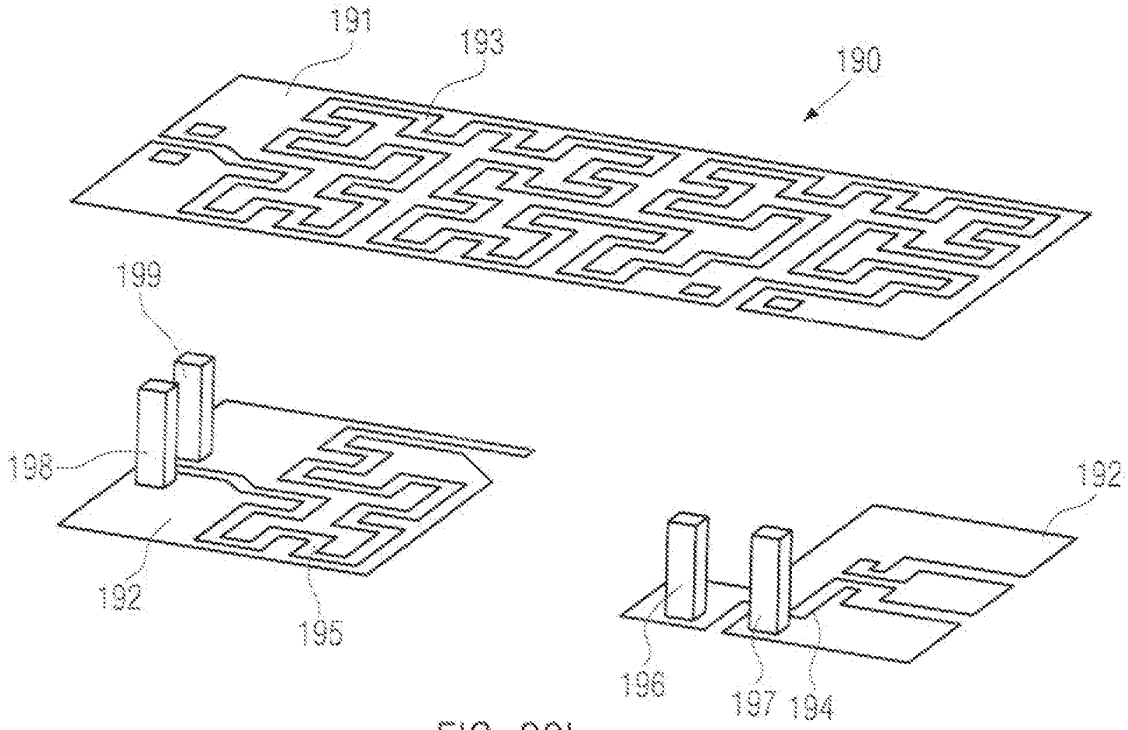


FIG. 20b

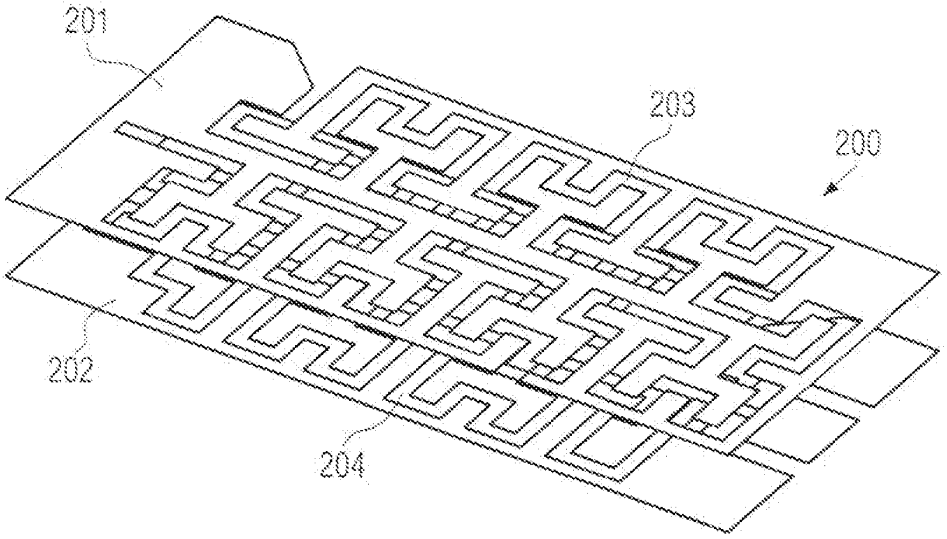


FIG. 20c

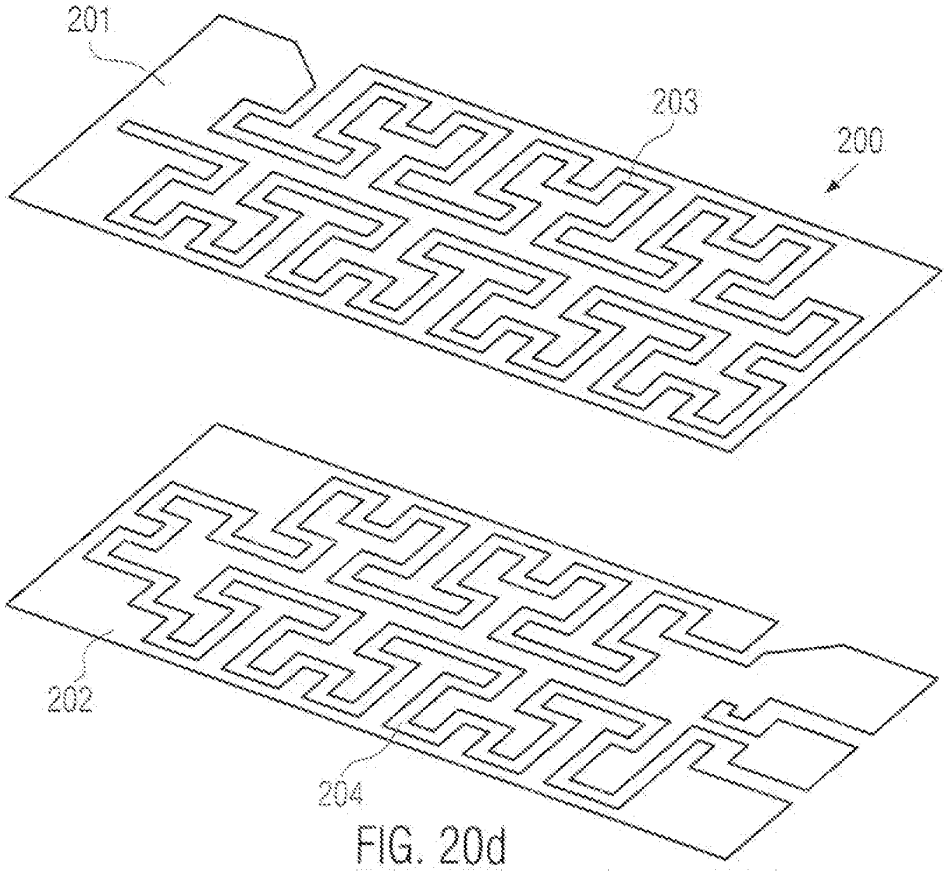


FIG. 20d

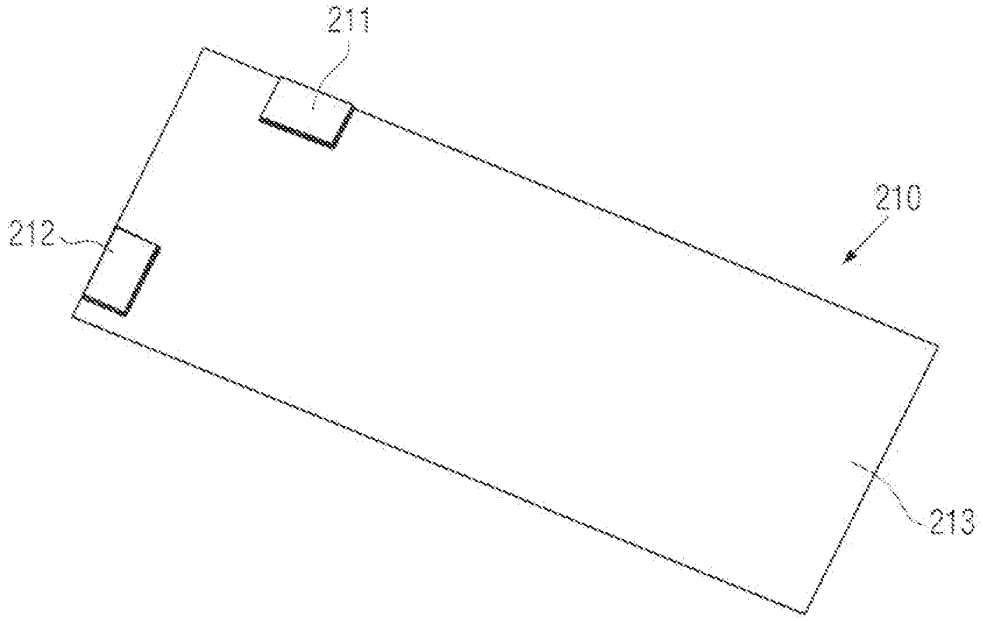


FIG. 21

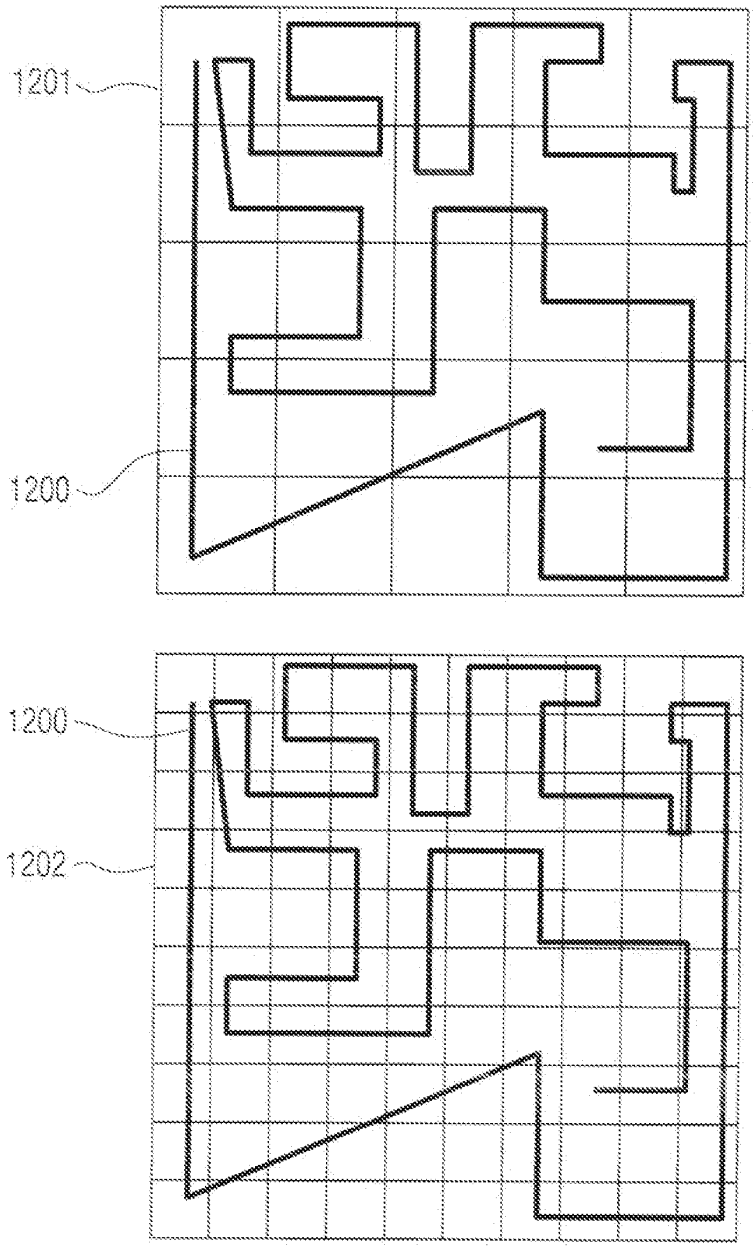


FIG. 22

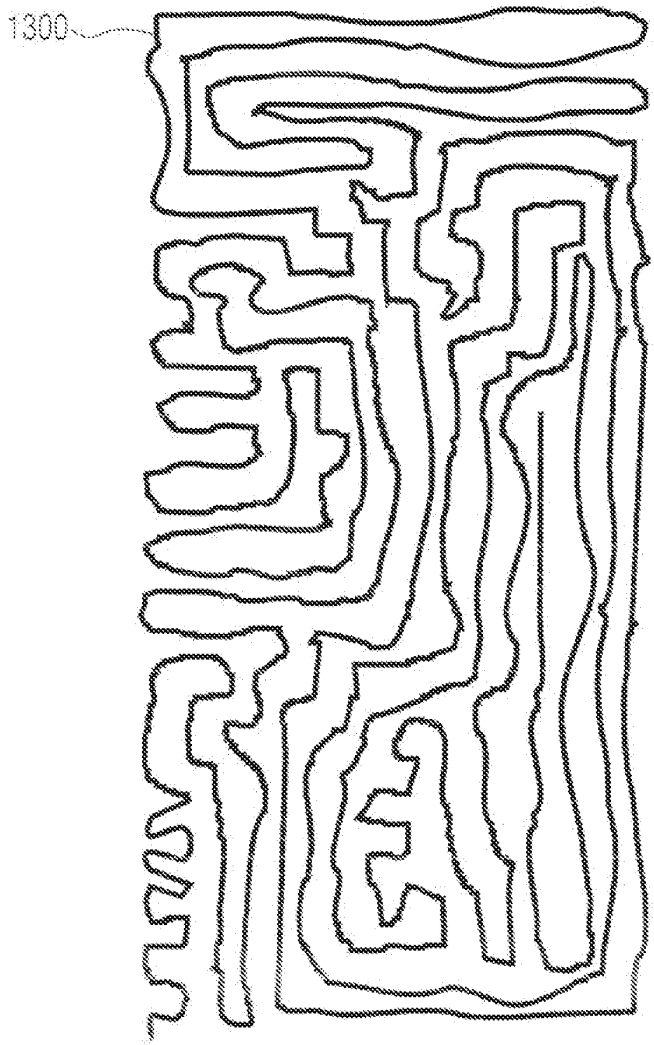


FIG. 23

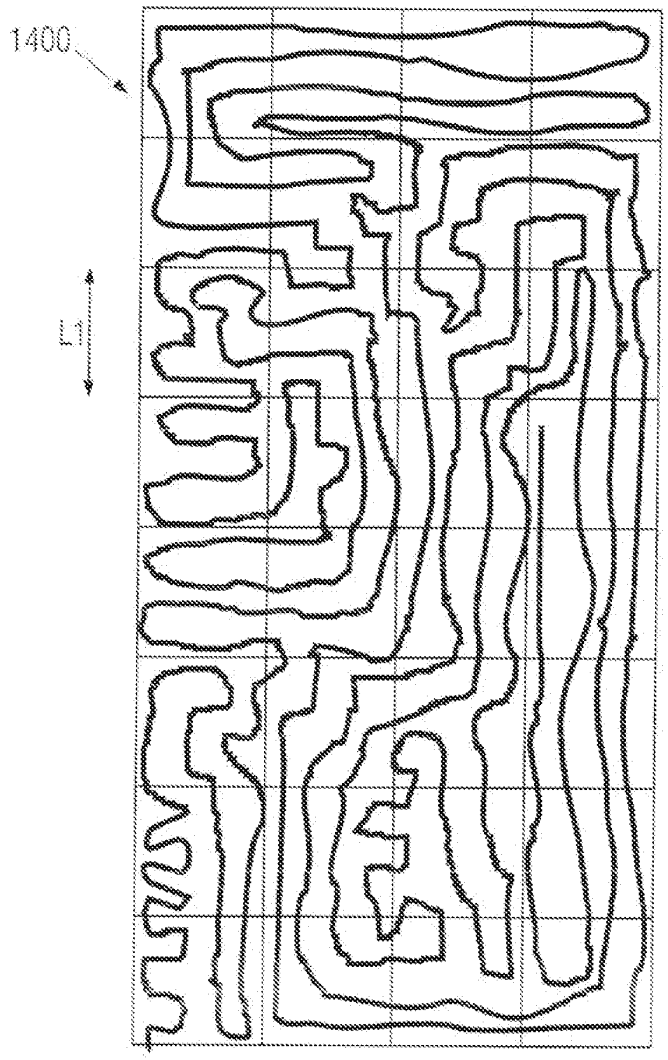


FIG. 24

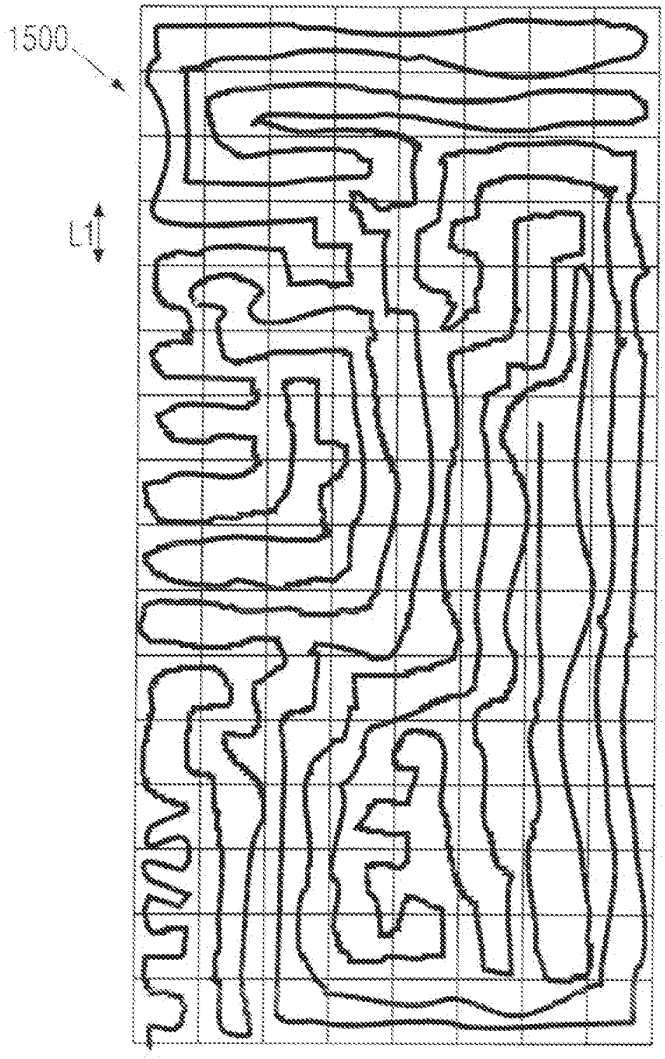


FIG. 25

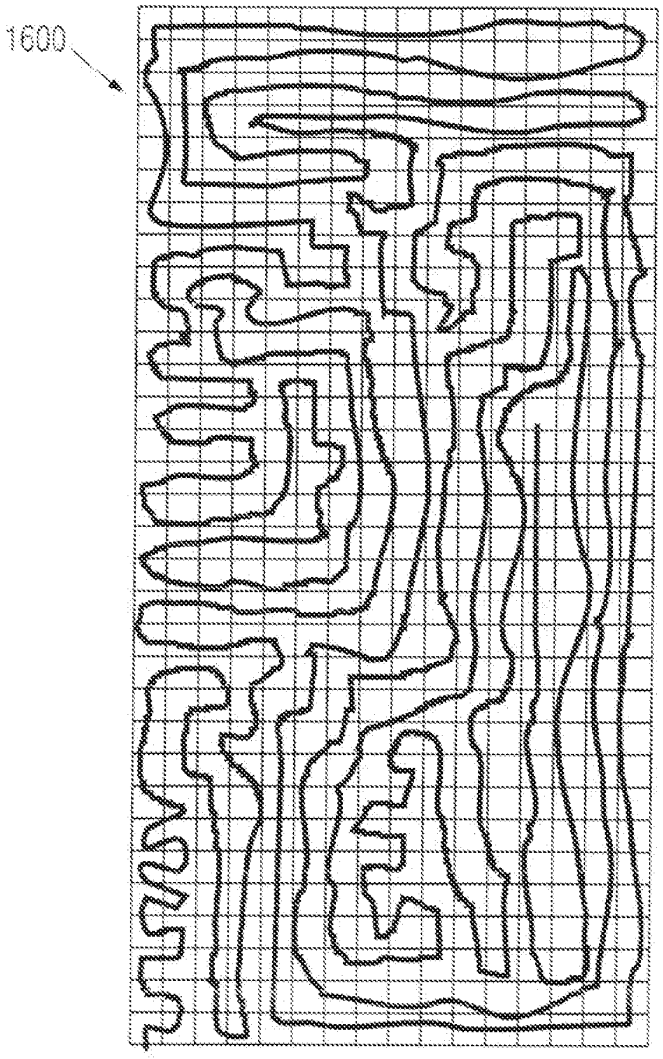


FIG. 26

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

PCT

(43) International Publication Date
16 November 2006 (16.11.2006)

(10) International Publication Number
WO 2006/120250 A2

(51) International Patent Classification:
H01Q 21/28 (2006.01) *H01Q 13/10* (2006.01)
H01Q 21/24 (2006.01) *H01Q 1/24* (2006.01)
H01Q 9/30 (2006.01) *H01Q 1/38* (2006.01)

(21) International Application Number:
PCT/EP2006/062285

(22) International Filing Date: 12 May 2006 (12.05.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

05104026.9	13 May 2005 (13.05.2005)	EP
60/680,593	13 May 2005 (13.05.2005)	US
06110437.8	27 February 2006 (27.02.2006)	EP
60/778,323	2 March 2006 (02.03.2006)	US

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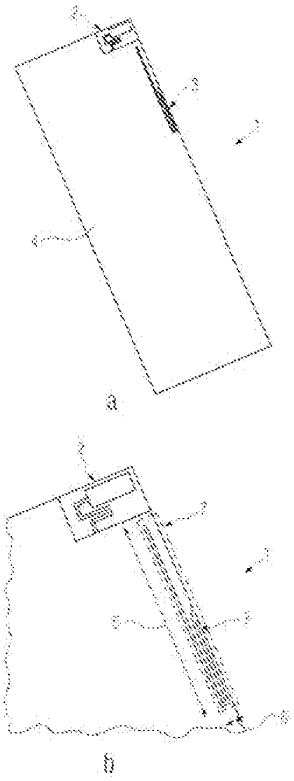
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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG,

[Continued on next page]

(54) Title: ANTENNA DIVERSITY SYSTEM AND SLOT ANTENNA COMPONENT



(57) Abstract: The present invention refers to an antenna diversity system comprising at least a first antenna and a second antenna wherein the first antenna substantially behaves as an electric current source or as a magnetic current source, and the second antenna substantially behaves as an electric current source or as a magnetic current source and a corresponding wireless device. Further the invention relates to an SMT-type slot-antenna component comprising at least one conductive surface or sheet of metal in which the pattern of a slot is created, at least one contact terminal accessible from the exterior of said component to electrically connect the conductive surface included in the slot-antenna component with the ground plane of a circuit board such as a printed circuit board and a corresponding wireless device.

WO 2006/120250 A2

SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

ANTENNA DIVERSITY SYSTEM AND SLOT ANTENNA COMPONENT

This application is related to the European patent applications EP 05104026 filed on May 13, 2005 and EP06110437 filed on February 27, 2006 and to the US patent applications US60/680,693 filed on May 13, 2005 and US60/778,323 filed on March 2, 2006. The priority of those four applications is claimed and they are incorporated herein by reference.

Background of the invention

The present invention relates to an antenna diversity system in particular to an antenna diversity system of a wireless device.

In known wireless systems, different mechanisms contribute to the propagation of a radio frequency signal. As the radiated electromagnetic waves travel from the emitter to the receiver, they encounter obstacles (like for example walls and furniture in indoor environments, or buildings, trees and vehicles in outdoor environments) and as a result some of the energy carried by the waves is absorbed, reflected, scattered and/or diffracted. Thus, not only the signal component that comes from the emitter following a direct path arrives at the receiver, but also other components of the same signal that follow either reflected, diffracted or scattered paths. However, since these other components follow longer paths, they arrive at a later time (i.e., with different phase) than the direct path. The propagation can be furthermore complicated by the fact that in some cases no direct path (or line-of-sight, LOS) will be possible between emitter and receiver.

In typical wireless systems the transmitted signal will encounter several obstacles, giving rise to a multiplicity of propagation paths, and signal components arriving at the receiver with different delays. Furthermore, since the transmitter, the receiver and the obstacles can change their position over time, the characteristics of the multipath propagation channel will be time-variant.

The multipath propagation results in the combination of several signal components with different phases at the receiving antenna. This out-of-phase addition can result in a temporary cancellation of the received signal (phenomenon known as fading), with the subsequent loss of information. This problem becomes more critical for wireless systems involving data transmission, because fading is responsible for the interruption of the communication, the loss of data (and subsequent increase in bit error rate, BER), and the decrease of the data bit rate. All these aspects degrade the quality of service (QoS) of the system.

An important technique used to overcome these impairments of the quality of communication available in the wireless channel is antenna diversity. The basic concept of diversity is to provide the receiver with more than one versions (also referred to as branches) of the transmitted signal, where each version is received through a different channel. If the channels are substantially independent (or uncorrelated), then the probability of having simultaneously a fading in all of them will be very small, which means that the signal formed from combining all the branches at the receiver will have many fewer deep fades than either one of the individual signals.

Antenna diversity is also useful in Multiple-Input Multiple-Output (MIMO) systems. In such systems, a transmitter uses a first set of antennas to transmit different data streams over the same wireless propagation channel. At the receiver, a second set of antennas (wherein said second set does not need to comprise the same number of antennas as the ones in said first set) provides a MIMO detector with a plurality of received signals. Each one of these signals comprises multipath components of different transmitted data streams. A MIMO detector is able to extract from the received signals at least some of the data streams sent by the transmitter. Therefore, the use of antenna diversity in MIMO systems makes it possible to attain higher data bit rates and/or higher capacity.

There are several ways of implementing diversity using more than one antenna like space diversity, polarization diversity and radiation pattern diversity. Although these techniques can improve substantially the QoS of the system, it is difficult to

implement an effective antenna diversity system in a wireless portable device (such as for instance a mobile phone, a smartphone, a PDA, a MP3 player, a headset, a USB dongle, a laptop, a PCMCIA or Cardbus 32 card) due to the reduced dimensions and form factors of current wireless devices, which will become even more critical in future devices as the trend is towards reducing even further their dimensions.

Space diversity is achieved by having at least two antennas separated in space as to obtain sufficiently low correlation between the signals received by any pair of antennas. It is known by a skilled-in-the-art person that low correlation will occur when the antennas are separated a distance of at least a half of the free-space operation wavelength of the antennas.

However, the typical dimensions of the printed circuit boards (PCB) of wireless devices makes space diversity difficult to implement in such devices and lead to a poor diversity gain (i.e., improvement in the QoS). Furthermore, the real estate requirements of several printed antennas or chip antennas (both in terms of antenna footprint and antenna clearance from ground plane) on the same PCB might be prohibitive for a typical wireless device. The problem will only aggravate as the trend is to put more functionality and services in smaller PCBs.

Polarization diversity takes advantage of the fact that the propagation phenomena in the wireless channel tend to be independent for orthogonal polarizations. This diversity technique can be implemented using two collocated antennas with orthogonal polarizations, or instead one cross-polarized antenna. Although this approach would ease the requirements of PCB area for the antenna, the shapes and form factors of real PCBs make it difficult to obtain nearly orthogonal polarizations.

Radiation pattern diversity uses directional antennas oriented to cover different angular regions of the space to obtain little correlation between the detected signals. However, as it happens with polarization diversity, the shapes and form factors of

real PCBs lead to antennas with fairly omnidirectional pattern, hence resulting in poor diversity gain.

Further the invention relates to an antenna in a package or an antenna component.

The current trend in the market of wireless handheld devices, and more generally wireless portable devices, is the addition of more and more functionality and added-value services (such as for instance but not limited to internet and/or email browsing, personal organizers, geo-positioning and emergency location services, short-range connectivity with peripherals, television and/or radio receivers using DVB-H, DMB or DAB standards, MP3 player, digital cameras, or digital video recorders and/or players) into the devices, while at the same time reducing their overall dimensions.

Typically, a wireless handheld device contains a multilayer PCB which carries the electronic components, modules and other circuitry of said device. One or more layers of the multilayer PCB contain tracks that interconnect the different electronic components or modules mounted on the PCB. Other layers of said PCB are used to power the electronic components or modules and to ground them. These layers are commonly referred to as the power plane and the ground plane respectively.

A technique commonly used to mount electronic components on the PCB is the surface mount technology (SMT). An SMT component can be mounted (for example by means of soldering) directly onto a surface of the PCB without requiring fitting components with wire leads into holes in the PCB. Moreover, an SMT component is usually smaller than its leaded counterpart because it has either no leads, or smaller leads. An SMT component can have short pins, flat contacts, a matrix of balls (Ball Grid Array or BGA), terminations on the body of the component (passives), or short leads in a gull-wing formation (Quad Flat Package or QFP).

As the dimensions of a wireless handheld device or a wireless portable device are reduced, so does its PCB, requiring a high density of components on the PCB. Since SMT allows electronic components to be smaller in size and be mounted on both

sides of the PCB of a handheld device, this technology has widely replaced through-hole technology in the electronics industry.

As far as the integration of the antenna into a wireless handheld device or a wireless portable device is concerned, small-sized antenna solutions requiring a small region of ground plane clearance are clearly preferred. Moreover, standard low-cost antenna solutions that can be used throughout a wide range of wireless devices with different shapes and form factors are highly desired.

In some cases, a wireless handheld device or a wireless portable device comprises an antenna printed on a layer of the multilayer PCB. However, printed antennas typically are not small in size, since their dimensions are approximately a quarter of an operating wavelength of the antenna. In addition to it, they have the disadvantage of not being modular, making it necessary to design the antenna to fit in a specific device. Therefore, for the sake of modularity, it is advantageous to embed an antenna into a standard SMT-type component featuring small dimensions and low profile, and that can be mounted on the PCB of a handheld device or a portable device.

Known SMT-type antenna components use monopole antennas or inverted-F antennas (IFAs), which despite achieving some degree of miniaturization (for instance by loading the antenna with a material with high dielectric constant) still require a ground plane clearance region around the extension of the SMT antenna component to enhance the radiation process of the antenna.

WO2004042868 discloses an integrated circuit (IC) package comprising an antenna. Although the antenna comprised in the IC package can take the form of a slot antenna, the document does not provide indication on how a conducting sheet internal to the IC package and containing the slot of a slot antenna should be connected to an external ground plane (such as for example that of a PCB) in order to ensure good grounding of said conducting sheet.

Moreover, in the case of an IC package comprising an antenna as described in WO2004042868, the antenna is fed with a radio-frequency (RF) feeding signal originating in a die also contained in the IC package (i.e., no coupling of the RF feeding signal from the outside of the IC package to the inside of said IC package is required).

Object of the invention

The present invention discloses a new antenna diversity system for wireless devices (such as for instance a mobile phone, a smartphone, a PDA, a MP3 player, a headset, a USB dongle, a laptop, a PCMCIA or Cardbus 32 card) that exhibits good diversity gain, while requiring little PCB area overhead.

One aspect of the invention relates to the technique to implement polarization diversity in a wireless device combining a first antenna and a second antenna, with the second antenna being a slot antenna and requiring very small area of the PCB.

According to the present invention, good polarization diversity can be obtained by appropriately choosing the orientation on the PCB, and by selecting the antenna type (i.e., whether a given antenna substantially behaves as an electric current source, or as a magnetic current source) for each one of the antennas comprised in the diversity system.

A diversity system for a wireless device 10 subject of an investigative study, like the one presented in Fig. 3, consists of a first antenna 12 placed on the top left corner of the PCB 11 of the wireless device 10, and a second antenna 13 placed on the top right corner of the PCB 11. For illustrative purposes, the first and second antennas 12 and 13 are surface mount technology (SMT) components mounted on the PCB 11, although either one could have been replaced by an antenna printed on the PCB 11. The placement and orientation of the first and second antennas 12 and 13 on the PCB 11, as well as the ground plane clearance 14 around the antennas has been selected to make the polarization of the first antenna 12 as orthogonal as possible to the polarization of the second antenna 13.

In some cases each antenna, the first antenna and the second antenna, can be for instance and without limitation a monopole antenna, an inverted-F antenna (IFA), a patch antenna, or a planar inverted-F antenna (PIFA).

The typical electrical results for a wireless device with the antenna diversity system of Fig. 3 are shown in Fig. 4. In this example, the antennas were tuned in the 2400 – 2500MHz band, as it can be observed in the input return losses of Fig. 4a. This frequency range has been selected just to illustrate the example, but the antennas could work in any frequency band included in the range from 400MHz to 12GHZ. The polarization pattern of the first antenna 12 and the second antenna 13, in Fig. 4b, shows that the angle between the two polarizations is smaller than 45 degrees (well below the desired 90 degrees for orthogonal polarizations). Therefore, the solution of Fig. 3 for polarization diversity in a wireless device has poor diversity gain.

The present invention relates to a slot-antenna component that can be mounted in a wireless handheld device, and generally in any wireless portable device, to enable the transmission and reception of electromagnetic wave signals.

It is an object of the present invention to provide a handheld or portable device (such as for instance a mobile phone, a smartphone, a PDA, an MP3 player, a headset, a USB dongle, a laptop computer, a gaming device, a digital camera, a PCMCIA or Cardbus 32 card), which comprises an antenna for mobile communications and/or wireless connectivity services, said antenna being a slot antenna, being at least partially embedded in a surface mount technology (SMT) component, and requiring very small area on a printed circuit board (PCB) of said handheld or portable device.

Another aspect of the invention relates to the corresponding technique to feed and to ground a slot-antenna component. Further aspects of the present invention relate to the control over the electrical parameters of the slot-antenna component, by appropriately selecting the placement and orientation of the slot-antenna component on the PCB of a handheld or portable device, and by carefully defining a portion of the slot on said PCB.

Another aspect of the invention relates to the technique to control the electrical parameters of the slot-antenna component (such as for instance its polarization) by appropriately selecting the placement and orientation of said slot-antenna component on the PCB of a handheld or portable device.

Summary of the invention

The above mentioned drawbacks are overcome with an antenna diversity system as of claim 1 and 47 and a wireless device as of claim 48. Further embodiments are disclosed in the dependent claims.

The present invention discloses a new antenna diversity system for wireless devices (such as for instance a mobile phone, a smartphone, a PDA, a MP3 player, a headset, a USB dongle, a laptop, a PCMCIA or Cardbus 32 card) that exhibits good diversity gain, while requiring little PCB area overhead.

One aspect of the invention relates to the technique to implement polarization diversity in a wireless device combining a first antenna and a second antenna, with the second antenna being a slot antenna and requiring very small area of the PCB.

In an antenna diversity system at least one operating frequency or frequency band of the two or more antennas is the same or at least partially overlapping.

The first antenna may be an electric current source and the second antenna may be a magnetic current source. The magnetic current source may be e.g. a slot antenna or a slot-loop antenna.

The first antenna may be e.g. a monopole, a dipole, a patch antenna, and IFA (inverted F-antenna) a PIFA (planar inverted F-antenna). Further it may be a multiband band antenna which has multiple operating frequency bands. In general any of those antennas may be formed by being printed as a conductive layer on a

circuit board or by being etched from a conductive layer of a circuit board. Circuit boards in general are also referred to by the term printed circuit board or in short PCB. A conductive layer of a circuit board preferably is adapted such that it may at the same time act as a ground plane.

In some examples, it will be advantageous to have the slot antenna inscribed in a rectangular area of width smaller than 1/50 of the free-space operating wavelength, and length smaller than 1/4 of the free-space operating wavelength. Being more general, in some embodiments the said width divided by the free-space operating wavelength of the slot antenna will be smaller than, or equal to, at least one of the following fractions: 1/10, 1/30, 1/50, 1/60, 1/70, or 1/80. In the same way, for some embodiments the said length divided by the free-space operating wavelength of the slot antenna will be smaller than, or equal to, at least one of the following fractions: 1/2, 1/3, or 1/4, or even smaller than, or equal to, at least one of the following fractions: 1/5, 1/6, 1/8. In some other instances, it will be advantageous that the sum of the length and the width of the rectangular area in which the slot is inscribed be smaller than 1/2 of the free-space operating wavelength, or even smaller than 1/4 of the free-space operating wavelength.

Furthermore, it will be advantageous in some cases that the separation between the two edges of the slot to be within a range from approximately the 0.08% of the free-space operating wavelength to approximately the 8% of the free-space operating wavelength, including any subinterval of said range. Some possible lower bounds and/or upper bounds within said range include: 0.08%, 0.16%, 0.32%, 0.5%, 1%, 2%, 4%, 6% and 8%.

The shape of the slot can comprise straight and curved segments, not necessarily all segments being of the same length. They may, however, also all, or all but one, two or three, be of the same length. In the same way, the separation between the conductive edges of each segment of the slot does not have to be the same for all segments, nor constant for any given segment (i.e., any segment of the slot can be tapered). The separation may, however, be the same for all segments, or all but one,

two or three segments. Further the separation may be constant in one, two three or more or all segments.

In some cases, it is advantageous to design the slot such that it is substantially parallel to the longer side of the PCB, because the currents excited on said PCB by the resonating mode of the first antenna tend to be substantially parallel to said longer side of the PCB. The same effect can be achieved if the longest straight segment of the slot is arranged substantially parallel to the longest extension or to the longest symmetry axis (symmetry axis which extends the longest way inside the PCB).

At least one end of the slot is preferably open. In this way short slot antennas can be realized. Further like this it is conveniently possible to connect such an open end to another slot of another conducting layer or surface or of a ground plane such that a combined slot is formed.

The slot antenna in some examples will be implemented as a slot printed or etched on the ground plane of the PCB, while in other cases the slot will be contained in a SMT type component mounted on the PCB of the wireless device. When the slot is contained in a SMT type component, said component will comprise a sheet of metal on which the slot is created. The SMT type component will provide at least one contact terminal accessible from the exterior of said SMT component to electrically connect said sheet of metal with the ground plane of the PCB. In some embodiments, this contact terminal can take the form of a pad, or a pin, or a solder ball.

It will be advantageous in some cases to define on the PCB a region of clearance of the ground plane on the orthogonal projection of the component on the PCB on which it is mounted. In other cases, there will be ground plane on a portion of the orthogonal projection of the SMT component on the PCB, but not under the orthogonal projection of the slot on said PCB.

Details of such a component are given in any of claims 52 to 76 and explained in more detail below and details of a wireless device with such a component are given in any of claims 77 to 109 and explained in more detail below.

Further it is advantageous, that at least two, three, four or more portions of the slot are parallel to each other. This may apply to straight and to non-straight segment. With this parallel arrangement very compact antennas can be achieved.

In order to maintain as much space as possible for other devices within the wireless device it will be advantageous to have the slot of the slot antenna occupying as little area as possible. Preferred values of the fraction which is occupied by the slot are indicated in claim 24.

In yet other cases, wherein the first antenna substantially behaves as an electric current source and the second antenna substantially behaves as a magnetic current source, good polarization diversity is achieved when the electric currents excited on at least a portion of the PCB by the radiating mode of the said first antenna are substantially parallel to the magnetic currents excited on at least a portion of the extension of the said second antenna.

In the context of this application, two directions are considered to be substantially parallel if they form an angle of less than, or equal to, approximately 30, approximately 20 or approximately 10 degrees.

It is also possible two have two antennas which are magnetic current sources such as e.g. slot or slot-loop antennas.

In some cases, the first antenna and the second antenna will be slot antennas aligned respectively along a first direction and a second direction, being said first direction substantially orthogonal to said second direction. In the context of this application, two directions are considered to be substantially orthogonal if they form an angle in the range from approximately 60 degrees to approximately 120 degrees, approximately 70 degrees to approximately 110 degrees or approximately 80

degrees to approximately 100 degrees. Also in the context of this application, the direction of slot can e.g. be defined by the direction of the longest side of the rectangular area in which said slot is inscribed.

In other cases, wherein the first and second antenna behave as magnetic current sources (for instance, but not limited to, slot antennas), good polarization diversity is achieved when the magnetic currents excited on at least a portion of the extension of the first antenna are substantially orthogonal to the magnetic currents excited on at least a portion of the extension of the second antenna.

Each of the first and second antenna or only one of those first and second antennas may have any of the characteristics of any of claims 6 to 10, 12 to 25. The ground plane of a circuit board on which the first and second antennas are provided may have the characteristic of claim 11.

Any slot antenna mentioned herein may be a multiband slot antenna.

It will also be possible to have two electric current sources as antennas.

In those cases, wherein the first and second antenna substantially behave as electric current sources (for instance, but not limited to, monopole antennas), good polarization diversity is achieved when the electric currents excited on the PCB by the radiating mode of the first antenna are substantially orthogonal to the electric currents excited on the said PCB by the radiating mode of the second antenna, in at least a portion of the PCB.

The antennas of the antenna diversity system have at least one operating frequency or frequency band in common. It will be, however, preferable to have at least two, three, four or more operating frequencies or frequency bands in common. Thereby an antenna diversity system can be achieved at multiple operating frequencies or frequency bands. Further at least one, two, three or more of the antennas of the antenna diversity system have operating frequencies or frequency bands which are not in common with the other antennas of the diversity system. This allows the use

of such an antenna for other applications where an antenna diversity system is not desired or required without the need of a separate antenna.

The antennas are preferably located on or close to corners of the ground plane. Thereby they are provided close to an area without a ground plane such that radiation can be effectively transmitted to the outside. The same applies to the location of an antenna on or close to an edge of the ground plane.

For symmetry reasons it is advantageous to place at least one antenna on or close to an edge of a ground plane and there on or close to the middle of the edge. Thereby currents in the ground plane which are induced in a direction perpendicular to the longest side or extension of the ground plane are not redirected in this longer direction of the ground plane and therefore a good polarization diversity can be achieved.

In some embodiments, it will be preferable to keep the separation between the first antenna and the second antenna small in order to facilitate the connection of the two antennas to a common radio frequency RF hardware part of the wireless device. However, in other embodiments it will be preferable to have the first antenna and the second antenna further apart to maximize the isolation between the first antenna and the second antenna.

Generally, the present invention can be arranged inside several kinds of wireless devices to facilitate the integration of the antennas in a way that it is compatible with high density of components on the PCB of the device. For miniaturization purposes, at least a portion of the curve defining the conducting trace, conducting wire or contour of the conducting sheet of at least one antenna of the diversity system will advantageously be a space-filling curve, a box-counting, a grid-dimension curve, or a fractal based curve. The conducting trace, conducting wire or contour of the conducting sheet of said at least one antenna might take the form of a single curve, or might branch-out in two or more curves, which at the same time in some embodiments will be also of the space-filling, box-counting, grid-dimension, or fractal kinds. Additionally, in some embodiments a part of the curve will be coupled either

through direct contact or electromagnetic coupling to a conducting polygonal or multilevel surface.

In some preferred embodiments the wireless device is operating at one, two, three or more of the following communication and connectivity services:In some preferred embodiments a wireless (e. g. handheld or portable) device including a slot antenna component according to the present invention is operating at one, two, three or more of the following communication and connectivity services: Bluetooth, 2.4GHz Bluetooth, 2.4 GHz WiMAX, ZigBee, ZigBee at 860 MHz, ZigBee at 915 MHz, GPS, GPS at 1.575 GHz, GPS at 1.227 GHz, Galileo, GSM 450, GSM 850, GSM 900, GSM 1800, American GSM, DCS-1800, UMTS, CDMA, DMB, DVB-H, WLAN, WLAN at 2.4 GHz-6GHz, PCS 1900, KPCS, WCDMA, SDARs, XDARS, DAB, WiFi, UWB, 2.4-2.483 GHz band, 2.471-2.497 GHz band, IEEE802.11ba, IEEE802.11b, IEEE802.11g and FM.

According to the present invention, good polarization diversity can be obtained by appropriately choosing the orientation on the PCB, and by selecting the antenna type (i.e., whether a given antenna substantially behaves as an electric current source, or as a magnetic current source) for each one of the antennas comprised in the diversity system.

The beforehand mentioned drawbacks of know antenna components are overcome by the SMT-type slot-antenna component of claim 52 and the wireless device of claim 77 and 109. Preferred embodiments are disclosed in the dependent claims.

The present invention discloses a slot antenna integrated in a SMT component that minimizes the ground plane clearance region needed on the PCB. Embedding a slot antenna in a discrete SMT component is difficult due to the necessity to ensure good grounding of the conducting sheet in which the slot has been created, and to the complexity to couple the feeding signal into the SMT component.

One aspect of the present invention relates to the grounding of the slot antenna integrated in an SMT component. Another aspect of the present invention refers to

the feeding means to couple an RF feeding signal into the SMT slot-antenna component.

Contrary to the disclosure of WO2004042868, an aspect of a slot-antenna component according to the present invention relates to the feeding means to couple an RF feeding signal coming from the outside of the SMT component into said SMT component to feed the slot contained inside the SMT component.

The present invention discloses a slot-antenna component for mobile communications and/or wireless connectivity services that can be mounted as a standard SMT component on the PCB of a handheld or portable device (such as for instance a mobile phone, a smartphone, a PDA, an MP3 player, a headset, a USB dongle, a laptop computer, a gaming device, a digital camera, a PCMCIA or Cardbus 32 card).

An SMT-type slot-antenna component according to the present invention comprises:

- At least one conductive surface (different from the conductive surface of the ground plane of the PCB) or a sheet of metal in which the pattern of a slot is created; and
- At least one contact terminal (hereinafter referred to as grounding terminal) accessible from the exterior of said component to electrically connect the conductive surface included in the slot-antenna component with the ground plane of the PCB;

With this component it is possible to provide a slot antenna as a separate component which can be connected from the outside. The antenna may further comprise:

- At least one contact terminal (hereinafter referred to as feeding terminal) to couple an electrical signal from the outside of the SMT-type slot-antenna component with the slot defined in said at least one conductive surface.

It will in principle also be possible to couple a feeding signal into the component indirectly by a capacitive or inductive coupling. For a good feeding, however, a direct electrical connection is preferred. This can be achieved by the feeding terminal. In any case the component has no internal means for generating an RF signal with which the antenna may be fed.

Further it will be preferred that the component further comprises a

- dielectric substrate that backs said at least one conductive surface or sheet of metal, or in which said at least one conducting surface or sheet of metal is embedded;

The dielectric substrate allows for the backing of thin metal layers and is a widely used technique for the preparation of components for the electronics industry.

The terms sheet of metal and conductive surface are used for the same namely a conductive layer supported by a circuit board or a rigid piece of metal such as e.g. a stamped metal piece.

The antenna may be part of an antenna diversity system. It may, however also not be part of an antenna diversity system depending on the requirements of the application.

A contact terminal can take the form of a pad, a pin, or a solder ball. In some embodiments according to the present invention, it is advantageous to use a single contact terminal as grounding terminal and as feeding terminal, while in others it is preferred to use a contact terminal as grounding terminal only or as feeding terminal only. Further multiple contacts may be provided each of which is only for grounding, only for feeding or for both.

Additional pads may be provided which are not electrically connected inside the component or to the ground plane or a feeding element of the circuit board. Those

pads may be useful fore mechanically holding the antenna component by the solder connection at that pad between the component and the circuit board.

In some embodiments according to the present invention, the SMT component can also include one or several electronic elements or circuits, or the SMT component can take the form of an IC package. When the slot-antenna component takes the form of an IC package, then the slot contained in said IC package is excited with an RF feeding signal coupled from the outside of said IC package, and not directly from a semiconductor die comprised inside said IC package.

In certain of these embodiments, the electronic elements or circuits included in the SMT component or IC package will be preferably placed within the SMT component or IC package in such a way that they are not on the projection of the slot contained in the SMT component.

In some other embodiments, a slot-antenna component may comprise more than one, two or three conductive surfaces in which a slot or a portion of a slot is created. By this technique it will be possible to "fold" the slot in vertical direction away from the PCB. Therefore the footprint area on the PCB required for such an antenna will be significantly reduced in comparison to antennas where the slot is "folded" in a plane parallel to the PCB surface plane. Most conveniently two conducting surfaces can be provided on the two opposite large sides of a circuit substrate. If a multilayer circuit substrate is used, further surfaces can be provided in order to form the slot antenna in the component.

The different surfaces may be connected or may remain unconnected. The connection may be done by a via hole or by a connection around the edge of a circuit substrate.

In order to protect a conducting layer it will be advantageous to cover that layer with a protection layer. This prevents corrosion. Further such a protection layer can be used to define terminals of the conducting layer which are then available for e.g. a solder connection.

The antenna characteristics can further be chosen by using open-ended or closed-ended slot geometries. Any end of the antenna may be open or closed.

In some embodiments it is advantageous to place grounding terminals to connect the conductive surface with the ground plane of the PCB close to at least two opposite edges of the slot-antenna component, preferably those two opposite edges that are the farthest apart from each other, so that the electric currents induced by the operation of the slot antenna on the conductive surface can flow through grounding terminals into the ground plane of the PCB as if the conductive surface and the ground plane of the PCB were one single conductive surface.

In certain cases it might be interesting to place a grounding terminal substantially close to at least two corners of said at least two opposite edges of the component, but preferably the four corners of said two opposite edges of said component.

Further it is preferred to extend one or more ground terminal along a major part of the length of an edge of the component or of the conductive surface. Preferably the ground terminal may extend along at least 40%, 50%, 60%, 70%, 80%, 90% or 95% of the length of an edge. Thereby a good connection of the conducting surface to the ground plane of the PCB is achieved. This is in particular the case where two grounding terminals extend along opposite edges such as the short and/or the long edges. One ground terminal may also be bent such that it is L- ,U- or O-shaped and is preferably provided along one, two, three or four neighboring edges.

Furthermore, in some examples it can be advantageous to place grounding terminals at two sides of a feeding terminal and substantially close to said feeding terminal. This arrangement can be used to effectively excite the slot.

Further in some cases it will be advantageous to provide the feeding terminals on two sides of the slot. Then it is possible to combine the slot with another slot by connecting the respective two edges of the two slots, thereby forming a larger slot.

In some embodiments the feeding means of the slot-antenna component comprise a feeding contact and a conductive strip. Said conductive strip can be advantageously printed or etched on the same conductive surface as the slot, thus making the feeding means coplanar with the slot. The conductive strip connects the feeding terminal with the edge of slot that is farther away from the contact terminal.

Preferably a clearance region is provided at least on one, two, or three sides of the feeding terminal. This is in particular useful if the terminal is only used for feeding purposes. If the feeding terminal is also used for grounding purposes such clearance might not be present.

Also for the conductive strip a clearance may be provided. This clearance may not be necessary if the conductive strip is provided on a different level as the conductive surface with the slot. If the conductive strip is provided on a different level it may be connected to the conductive surface of the slot by a via hole or capacitive or inductive coupling. In the same way the coupling between the feeding terminal and the conductive strip may be made by capacitive, inductive or direct electrical contact coupling.

It will be advantageous in some cases to define on the PCB of the wireless device a region of clearance of ground plane on the orthogonal projection of the slot-antenna component on the PCB on which it is mounted. In other cases, there will be some ground plane on a portion of the orthogonal projection of the slot-antenna component on the PCB, but not under the orthogonal projection of the slot created in the conductive surface of the slot-component on the PCB. Yet in other embodiments, there will be ground plane also in a portion of the orthogonal projection of said slot on the PCB. In some examples, the fraction of the projection of the slot occupied by ground plane will be less than, or approximately equal to, a 50%, 40%, 30%, 25%, 20%, 10% or 5% of the projection of the slot on the PCB.

In order to form accepting pads on the PCB for receiving the terminals of the antenna component without however unnecessarily reducing the ground plane

clearance it is advantageous to provided protrusions of the ground plane which extend into clearance.

Further the size of the area of the clearance e.g. given in mm^2 may be smaller than the size of the antenna component.

In certain embodiments the slot-antenna component is electrically coupled by means of feeding terminals with a slot created on the ground plane of the PCB of the wireless (e.g. handheld or portable) device. In other words, a slot antenna is formed by combining the slot pattern printed or etched in the ground plane of the PCB with the slot pattern included in the SMT component. Having a portion of the slot antenna printed or etched in the ground plane of the PCB can be advantageous, particularly because this:

- allows the fine tuning of the antenna to account for changes in the dimensions and/or form factor of the ground plane of the PCB to which the slot-antenna component is connected, or the effects of dielectric (e.g., plastic) casings or enclosures, by simply acting on the portion of the slot antenna printed on the ground plane of the PCB.

- provides the PCB designer with more flexibility when laying out the different electronic components on the PCB as the shape of the portion of slot antenna created in the ground plane can be selected for example to meet space constraints, or to minimize the distance of the antenna to the RF circuit.

Since this is achieved by acting only on the portion of the slot printed or etched on the ground plane of a PCB, while leaving the geometry of the slot contained in a conductive surface of an SMT component unchanged, such embodiments are effective in providing a standard component that can be used in a great variety of application environments.

In order to arrange the antenna such that as much space as possible is left over for other components it is advantageous to orient an edge and in particular a long edge of the SMT-type slot antenna component substantially parallel to the short or long edge of the circuit board.

The antenna component should not be to far away from the edge of the circuit board. This facilitates providing a clearance and assures good radiation characteristics.

In some embodiments the antenna component is preferably located on or close to the middle of an edge and in particular on or close to the middle of a long edge of the circuit board or the ground plane. A symmetric location with respect to the ground plane can provide a more predictable polarization characteristic since currents induced in the ground plane are not redirected in an asymmetric way by the shape of the ground plane. This may apply even if the antenna itself is not symmetric but the location of the antenna on the ground plane is symmetric or almost symmetric.

The slot of the component may be excited by balanced or unbalanced feeding. This can be done with the help of a coplanar or coaxial transmission line or a microstrip transmission line.

In a preferred embodiment there are two slot-antenna components. This allows for the coverage of different frequencies or frequency bands or the coverage of the same frequency or frequency bands in a diversity system, such as a polarization and/or space diversity system or in MIMO systems. For a polarization diversity system it will be advantageous to provide two slot-antenna components (or their longer sides) substantially orthogonal to each other.

In general the (e.g. two, three or more) antennas of an antenna diversity system may be preferably identical apart from their orientation. This applies in particular to the case where slot antennas in the ground plane and/or in a component are used for forming the diversity system.

The circuit board may comprise a pad which is connected to the feeding pad. Depending on the feeding scheme this pad may or may not be connected to the ground plane of the circuit board.

By combining the slot of a ground plane and the slot of a slot-antenna component it is possible to obtain combined slots which are open at none, one, or two ends.

If such a combined slot is provided this combined slot may be excited by exciting the slot portion of the antenna component or the slot portion of the ground plane. The latter may be preferred since with this technique it is possible to connect to RF-generator directly with the ground plane of the circuit board on which the RF-generator itself is provided.

If the slot of the antenna component or a combined slot (see above) has a closed end it is preferable to excite the slot at a certain distance from the closed end. The distance along the slot geometry divided by the free space operating frequency is preferably less than 0.002, 0.004, 0.008, 0.012, 0.016, 0.025, 0.033, 0.04, 0.08, 0.1 or 0.15.

In some preferred embodiments a wireless (e. g. handheld or portable) device including a slot antenna component according to the present invention is operating at one, two, three or more of the following communication and connectivity services: Bluetooth, 2.4GHz Bluetooth, 2.4 GHz WiMAX, ZigBee, ZigBee at 860 MHz, ZigBee at 915 MHz, GPS, GPS at 1.575 GHz, GPS at 1.227 GHz, Galileo, GSM 450, GSM 850, GSM 900, GSM 1800, American GSM, DCS-1800, UMTS, CDMA, DMB, DVB-H, WLAN, WLAN at 2.4 GHz-6GHz, PCS 1900, KPCS, WCDMA, SDARs, XDARS, DAB, WiFi, UWB, 2.4-2.483 GHz band, 2.471-2.497 GHz band, IEEE802.11ba, IEEE802.11b, IEEE802.11g and FM.

Any reference in this document to a or the free-space operating wavelength may refer to any free-space operating wavelength of an antenna or in particular to the largest free-space operating wavelength of different possible operating wavelengths.

In wireless devices the possible free-space operating wavelengths are usually given by the RF-generator or RF-receiver circuit which may be included in the wireless device.

List of figures

Further characteristics and advantages of the invention will become apparent in view of the detailed description which follows of a preferred embodiment of the invention given for purposes of illustration only and in no way meant as a definition of the limits of the invention, made with reference to the accompanying drawings, in which shows:

Fig. 1 an antenna diversity system of the present invention;

Fig. 2 typical electrical performance of the device of Fig. 1;

Fig. 3 the antenna diversity system of an investigative study;

Fig. 4 typical electrical performance of the device of Fig. 3;

Fig. 5 examples of the possible locations of two antennas according to the present invention;

Fig. 6 an example of an antenna diversity system of the present invention;

Fig. 7 another example of an antenna diversity system of the present invention;

Fig. 8 further examples of antenna diversity systems of the present invention and some further illustrations of terms used within this document;

Fig. 9, Fig. 10 further examples of antenna diversity systems of the present invention;

Fig. 11 an example of an antenna diversity system with two slot antennas according to the present invention.

Fig. 12 (a) a three dimensional view of a slot antenna component;(b) a view onto the slot without the dielectric substrate;

Fig. 13 different possible locations of an antenna component on the circuit board;

Fig. 14 a schematic view of an example of the ground plane clearance and the slot-antenna component location;

Fig. 15 (a) a three dimensional view of a slot antenna component; (b) a view onto the slot without the dielectric substrate.

Fig. 16 (a) a schematic view of an example of the ground plane clearance and a possible slot-antenna component location; (b) the ground plane together with the slot antenna component;

Fig. 17 (a) a three dimensional view of a slot antenna component; (b) a view onto the slot without the dielectric substrate.

Fig. 18 different possible feeding schemes of the arrangement of Fig. 15;

Fig. 19 different possible feeding means for the arrangement of Fig. 15;

Fig. 20 multiple conducting surfaces of a slot antenna component;

Fig. 21 a possible arrangement of two slot antenna components on a circuit board;

Fig. 22 example of a box counting curve located in a first grid of 5x5 boxes and in a second grid of 10x10 boxes;

Fig. 23 example of a grid dimension curve;

Fig. 24 example of a grid dimension curve located in a first grid;

Fig. 25 example of a grid dimension curve located in a second grid;

Fig. 26 example of a grid dimension curve located in a third grid.

Detailed description of figures

Fig. 1 shows an example of a top plan view of a diversity system 1 for a wireless device formed by two antennas 2, 3 in which one antenna 2 is a component or chip antenna, and the other antenna is a slot antenna 3 printed on the PCB. Fig. 1a shows a general view of the PCB (with dimensions 100mm x 40mm for the purpose of the example) carrying the two antennas 2, 3 and Fig. 1 b shows a detailed view of Fig. 1a of the region that contains the two antennas 2, 3.

In the example of Fig. 1, and without being a limitation of the invention, the slot 3 has been created on the ground plane of the PCB 4 on its right hand side. The shape of the slot 3, and the length and widths of each one of the segments that form the said slot 3, can be selected to meet the requirements of resonance frequency, electrical performance, and maximum PCB area constraint, of a given wireless device. The design of the slot 3 and its orientation with respect to the PCB 4 is selected such that the slot 3 is substantially parallel to the direction of the currents excited on the PCB 4 by the resonating mode of the first antenna 2, at least on a portion of the PCB 4.

Two segments of the slot 3 including to longest straight segment are oriented parallel to the edge of the PCB. They are connected by an slot section which is

oriented perpendicular to the long two sections. The slot 3 ends open ended since it ends on one edge of the ground plane. The other end of the slot 3 is closed.

In Fig. 1 the first antenna 2 is located in or on a corner of the PCB. The second antenna 3 is located on or close to the edge of the PCB but separated from the corner by the first antenna 2. In Fig. 1 the entire PCB is covered with a ground plane (apart from the place where the slot 3 is formed). Further a portion of the ground plane may be omitted close to the first antenna 2 in order to form a clearance for the first antenna 2.

An rectangle 7 in which the slot 3 is inscribed is shown in Fig. 1b. The width of the rectangle is indicated with reference sign 6 and the length with reference sign 5.

Fig. 2 shows the typical electrical performance of the antennas of the wireless device shown in Fig. 1. Fig. 2a shows the return loss of each antenna and isolation between antennas and Fig. 2 b shows polarization pattern of each antenna.

In Fig. 2 for the purpose of the example, and without loss of generality, the operation band has been selected to be 2400 – 2500MHz. As it can be observed, the two-antenna solution of the example provides two polarizations that form the angle of approximately 98 degrees (substantially close to the desired 90 degrees for orthogonal polarizations). In the context of this patent application, two polarizations are considered to be substantially orthogonal if the angle formed by the said two polarizations is in the range from approximately 60 degrees to approximately 120 degrees, from approximately 70 degrees to approximately 110 degrees or from approximately 80 degrees to approximately 100 degrees.

Fig. 5 shows a top view of some implementations of the diversity system for wireless devices comprising a slot antenna (black thick line) on the PCB (large rectangle) of the device. This Fig. presents some possible embodiments for the present invention of a diversity system for a wireless device comprising a slot antenna. For example, isolation between the antennas on the PCB for the case of Fig. 5b is expected to be

better than for the case of Fig. 5a, as the separation between the antennas is larger, although this will complicate the feeding scheme of the two antennas.

The arrangement of Fig. 5a corresponds to that of Fig. 1. In Fig. 5a and 5b the two antennas 20, 21 and 22 ,23 are located close to the same edge of the PCB. In Fig. 5c they are located on or close to opposite edges of the PCB. In Fig. 5d the slot 27 is located along and close to the middle line of the PCB. It ends in a clearance area of the fist antenna such that one end is open and the other end is closed. In Fig. 5e and 5f the slots have two closed ends each. The slot antenna 29 is located parallel and close to the longer edge of the PCB (Fig.5e). In Fig. 5f the slot is located close to the middle line.

In Fig. 5a through 5f the slot antenna and its longest straight segment is arranged in parallel to the longer edge or side of the PCB while in Fig. 5g the slot antenna is located close to and in parallel to a short edge of the PCB. The slot in Fig. 5g ends at the short edge of the PCB (upper edge).

Fig. 5h and 5i show that the slot antenna may have non-straight segments. In Fig. 5h two curved segments are in parallel.

Fig. 6 shows an example of a diversity system 40 for a wireless device formed by two antennas 42, 43 in which one antenna 43 is a slot antenna, and the other antenna 42 is an IFA printed on the PCB 41 of the device. In the area (smaller upper rectangle) of the IFA no ground plane is provided on the PCB, such that a clearance is given. The slot is formed in an area (lower rectangle) where there is a ground plane.

Fig. 7 shows an example of a diversity system 50 for a wireless device formed by two antennas in which one antenna is a slot antenna 53, and the other antenna is a multiple-band antenna 52. The multiple-band antenna 52 is used for mobile phone communications, but also includes, as one of its operating bands, the same frequency band as the one of the slot antenna. In the area of the multiple-band antenna no clearance may be given, such that e.g. a patch antenna is provided as a

multiple-band antenna. The slot antenna 53 is provided separated from the multiple-band antenna 52. In Fig. 7 the multiple-band antenna 52 is shown in a position shifted a little to the left and upwards. This is only to show that there may be a separation between the PCB 51 and the antenna 52. In general the antenna 52 will be located well above the PCB 51 such that the right, top and left edge will coincide.

Fig. 8 shows examples of a diversity system 60 for wireless devices comprising a first antenna 63, 67, 70 integrated in a semiconductor package (AiP: Antenna in Package) that is mounted on the PCB 61 of the device and a second antenna being: in Fig. 8a a component or chip antenna 62; or in Fig. 8b an antenna (here an IFA 65) printed on the PCB 61; or in Fig. 8c a multiple-band antenna with some bands used for cellular communications, but also with a band at the same frequency band as the one of the first antenna 70.

At the first antenna 63, 67 and 70 a clearance 64, 69 of the ground plane is provided. The AiP component is provided partially above the ground plane and partially above the clearance. In Fig. 8b the clearance 66 for providing the IFA antenna 65 and a clearance for the AiP component are joint such that only one clearance is given.

In Fig. 8d a PCB is shown with a first antenna 71 in the upper right corner and another antenna 72 provided on the PCB. The antenna 72 is close to the middle 74 of an edge 73 of the PCB. The edge 73 has a length l such that the middle of the edge is given at a distance l/2 from the top or bottom edge. The antenna 72 has a rectangular outer shape or is inscribed in a rectangular area. The rectangle has an extension e1 in the vertical direction and e2 in the horizontal direction. In the vertical direction the antenna 72 is not farther away from the middle 74 than a separation s1 which is smaller than e1. In the horizontal direction the antenna 72 is not farther away than a separation s2 which is smaller than the extension e2 in that direction.

Fig. 8e shows the longest extension 76 of a PCB 75.

Fig. 8f shows the separation 79 between two antennas 77 and 78. The separation is given by the shortest distance between any antenna part such as a part of the slot of a slot antenna or the part of conductive portion of a monopole antenna or the like.

Another aspect of the invention relates to the technique to implement space diversity and/or polarization diversity in a wireless device combining at least two antennas, wherein at least one of the at least two antennas is an antenna integrated in a semiconductor package, as depicted in Fig. 8a to Fig. 8c. In those figures, the antenna-in-package (AiP) module 63, 67, 70 comprises an antenna and an electronic circuit (like for example and without limitation a semiconductor die) inside the same package. In some examples, the integration of the antenna inside the semiconductor will contribute to reduce the PCB area overhead (in terms of antenna footprint and antenna clearance from ground plane) of having that additional antenna on the wireless device to form part of the diversity system.

In some examples, the diversity system will comprise at least an antenna integrated in a semiconductor package, and at least another antenna that can be a monopole antenna, and IFA, a patch antenna or a PIFA.

Fig. 9 shows some implementations of the diversity system 80 for wireless devices comprising an antenna integrated in a semiconductor package that is mounted on the PCB of the device. In Fig. 9a the two antennas 82 and 81 are provided on the same edge of the PCB but on opposite corners of the edge. In Fig. 9b one antenna 83 is located close to the middle of the left edge of the PCB, which means close to the middle of one of the longer edges of the PCB. The other antenna 84 is provided in or on a corner of the opposite edge of the PCB.

In comparison to Fig. 9b in Fig. 9c the two antennas have been exchanged.

Fig. 10 shows an example of a diversity system 90 for a wireless device formed by two antennas 91, 92 in which one antenna is a slot antenna, and the other antenna is an antenna integrated in a semiconductor package mounted on the PCB 93 of the device.

In Fig. 11 an embodiment of a diversity system for a wireless device formed by two antennas in which the two antennas are slot antennas is shown. The two antennas are provided on or close to neighboring edges and are substantially parallel to their respective edges. Both are open at one end. They are oriented substantially orthogonal to each other. Both slot antennas are provided as slots in the ground plane but may nevertheless also be provided as slot antennas in package.

Description of the preferred embodiments

In some embodiments, the present invention is used to obtain a diversity system for a wireless device that exhibits good diversity gain and requires little PCB area overhead.

Embodiment 1:

In this embodiment (for instance, the one shown in Fig. 1), the wireless device with diversity system comprises a slot antenna 3 printed or etched on the ground plane of the PCB 4, and an antenna component (or chip antenna) 2 that can be mounted on the PCB 4 as a SMT component.

Embodiment 2:

This other embodiment, represented in Fig. 6, implements a diversity system for a wireless device combining a slot antenna 43 printed on the PCB 41 and a printed monopole antenna or IFA 42.

Embodiment 3

In another example in Fig. 7, the diversity system of the wireless device comprises a first antenna 53 being a printed slot antenna, and a second antenna 52. The second antenna 52 is for operating not only in the same frequency band as the one of the first antenna 53, but also operating, at least, at some other frequency band used for mobile telephone systems. In some cases, the said second antenna 52 will be advantageously a monopole antenna, an IFA, a patch antenna, or a PIFA.

Embodiment 4:

A further embodiment of the wireless device with diversity system shown in Fig. 10 comprises a printed slot antenna 92, and an antenna integrated in a semiconductor package 91, wherein the package can be of any of the technologies and architectures used in the semiconductor industry. Some basic architectures are for example single-in-line (SIL), dual-in-line (DIL), dual-in-line with surface mount technology DIL-SMT, quad-flat-package (QFP), pin grid array (PGA) and ball grid array (BGA) and small outline packages. Other derivatives are for instance: plastic ball grid array (PBGA), ceramic ball grid array (CBGA), tape ball grid array (TBGA), super ball grid array (SBGA), micro ball grid array BGA® and leadframe packages or modules.

Embodiment 5:

In this example, see Fig. 8a, the wireless device with diversity system 60 comprises an antenna component 62 and an antenna integrated in a semiconductor package 63 mounted on the PCB 61. Region 64 on the PCB 61 constitutes the clearance region around the antennas (i.e., the region on the PCB 61 is free from ground plane).

Embodiment 6

Another embodiment, in Fig. 8c, discloses a diversity system for a wireless device comprising a first antenna 70 being an antenna integrated in a semiconductor package, and a second antenna 68. The second antenna 68 operating not only in the same frequency band as the one of the first antenna 70, but also operating, at least, at some other frequency band used for mobile telephone systems. In some cases, the said second antenna 68 will be advantageously a monopole antenna, an IFA, a patch antenna, or a PIFA. Region 69 on the PCB 61 is the ground plane clearance region for the first antenna 70.

Embodiment 7

In yet another embodiment as the one of Fig. 8b, the diversity system for a wireless device is implemented combining an antenna integrated in a

semiconductor package 67 and a monopole antenna or IFA 65 printed on the PCB 61. Region 66 on the PCB 61 is free from ground plane (i.e., clearance region around the antennas).

Embodiment 8:

This embodiment, represented in Fig. 11, implements a diversity system 100 for a wireless device combining a first slot antenna 102 and a second slot antenna 103. The said first slot antenna 102 is oriented on the PCB 101 in such a way that excites a radiation mode on said PCB 101 responsible for radiation along a first polarization. The said second slot antenna 103 is oriented on the PCB 101 in such a way that it excites a radiation mode on said PCB 101 responsible for radiation along a second polarization, wherein the second polarization is substantially orthogonal to the said first polarization.

More detailed description of slot-antenna component

Fig. 12 shows an example of slot-antenna component 110 according to the present invention including a conductive surface 111 (see white area in gray or pointed area), in which a slot 113 has been created, a dielectric substrate112, five grounding terminals 115 and feeding means comprising a feeding terminal 114. In Fig. 12a a perspective bottom view of the slot-antenna component (i.e., as seen from the side of the component facing the PCB on which it is to be mounted) is shown. Fig. 12b is a top view of the component (i.e., as seen from the side of the component not facing the PCB on which it is to be mounted) in which the dielectric substrate 112 has been removed to observe the slot 113 in the conductive surface 111 of the component 110 and the contact terminals 114, 115.

The conductive surface 111 is backed by a dielectric substrate 112. In this particular example of Fig. 12, and without limiting purposes, the contour of the slot 113 is inspired in the Hilbert curve; however, other shapes could also be used. In fact, the shape of the slot 113, and the length and width of each one of the segments

that form said slot 113, can be selected to meet the requirements of resonance frequency, electrical performance, and maximum size, of a given SMT component.

In a preferred embodiment, the conductive surface 111 is covered by another dielectric layer (such as for example a layer of ink, or a layer of protective epoxy coating for environmental protection), in which some windows are left in order to create one or more contact terminals 114,115 of the component 110. In Fig. 12, the slot-antenna component 110 comprises one feeding terminal 114 and several grounding terminals 115a to 115e. The contact terminals 114,115 have been depicted as square pads, although they could be shaped differently, or take the form of pins or BGA balls.

All contact terminals 114, 115 are arranged on or close to the edge of the conductive surface 111 and at the same time on or close to the edge of antenna component 110.

In Fig. 13 examples of how a slot-antenna component 110 can be placed on a substantially rectangular PCB 121 of a wireless (e.g. handheld or portable) device are shown. In Fig 13a the longer dimension of the slot-antenna component 110 is aligned with one of the longer edges of the PCB121, and substantially centered along said edge. Fig. 13b relates to the case where the longer dimension of the slot-antenna component 110 is aligned with one of the longer edges of the PCB 121, and substantially close to a corner of said edge and in Fig. 13c the longer dimension of the slot-antenna component 110 is aligned with one of the shorter edges of the PCB121, and substantially close to a corner of said edge. It may also be centered along the short edge.

In Fig. 13a the component 110 has been mounted close to one of the long edges of a substantially rectangular PCB 121. In other cases, as in the example of Fig. 13c, the component 110 is mounted substantially close to a shorter edge of the PCB 121, and aligned with said shorter edge.

Fig . 14 provides a detailed view of the PCB of Fig. 13 magnifying the region in which the slot-antenna component 110 is mounted, and showing the ground plane clearance 132 in that region of the PCB and the footprint of the pads 134, 135 to accept the slot-component of Fig. 12.

The major region in Fig. 14 with the zig zag-style line indicates the ground plane 131 of the PCB 121. The outline of the component 110 on the PCB 121 is represented by means of rectangle 130 in dashed line. Inside rectangle 130, there is a region 132 in which there is a clearance of the ground plane 131. In other words, the ground plane 131 extends underneath the projection of the component 110 leaving a region of clearance 132 smaller than the size of the component 110. Within the rectangle 130, there is the footprint of the accepting pads 135 for the grounding terminals 115. Inside rectangular region 130 there is also the accepting pad 134 for the feeding terminal 114. In a preferred embodiment, pad 134 is not connected to the ground plane of the PCB 131.

As can be seen in Fig. 14 the accepting pads 135 are formed in the shape of protrusions extending into the ground plane clearance 132. The accepting pad 134 is provided between two pads 135 which are provided just next to the side of the accepting pad 134. Four of the five accepting pads 135 are provided in the corners of the clearance 132.

In Fig. 15 an example of a slot-antenna component 140 according to the present invention including a conductive surface 141 (see white area in gray or pointed area) in which a slot 143 has been created is shown. Further a dielectric substrate 142 with contact terminals 144, 145 for grounding purposes and contact terminals 144 to couple electrically said slot with a slot section printed or etched in the ground plane of a PCB are shown. Fig. 15a shows a perspective bottom view of the slot-antenna component 140 and Fig. 15b a top view of the component 140 in which the dielectric substrate 142 has been removed to observe the slot 143 in the conductive surface 141 of the component 140 and the contact terminals 144, 145.

The component 140 can also include other dielectric layers, such as for instance a cover ink layer. Again in this particular example, and without limiting purposes, the contour of the slot 143 is inspired by the Hilbert curve; however, other shapes (including periodic, irregular, or even random-like shapes) could also be used. In Fig. 15, the slot-antenna component 140 comprises three contact terminals: two of them 144 are used as feeding terminals and also as grounding terminals while the third contact terminal 145 is used as grounding terminal only. In this example, contact terminals 144 are shaped as being substantially square pads, while contact terminal 145 is shaped as being a rectangular pad, however, the contact terminals 144, 145 could have been shaped differently. The contact terminal 145 extends along more than 50% and in particular more than 90% of the length of the short edge of the conductive surface 141. A grounding terminal may also extend along more than a certain percentage of the length of a short or long edge of the component 140 or conductive surface 141.

The slot-antenna component 140 can be mounted in a similar way to the component 110 on a PCB 121 as the one shown in Fig. 13. However, the distribution of the ground plane on said PCB 121 is different.

In Fig. 16 a detailed view of the PCB 121 of Fig. 13 is provided magnifying the region in which the slot-antenna component 140 of Fig. 15 is mounted. Fig. 16a shows the distribution of the ground plane 151 within the PCB, the ground plane clearance 152 in the projection of the slot-antenna component, the footprint of the pads 154, 155 to accept the slot-component of Fig. 15 and the slot section 153 printed or etched on the ground plane of said PCB. In Fig. 16b a view is provided showing the coupling of the slot 143 contained in the component 140 of Fig. 15 with the slot section 153 printed or etched on the ground plane 151 of the PCB to form a single slot antenna. This single slot antenna has a combined slot.

The ground plane 151 has a region of clearance 152 underneath the projection of the component 140, which is indicated by rectangle 150 in dashed line. The ground plane 151 extends partially underneath the projection of the component 140 within the rectangular region 150. Inside said region 150 there is the footprint of the

accepting pads 154, 155 for the contact terminals of the component 144, 145. The ground plane 151 further comprises a slot section 153 that is connected to the accepting pads 154.

Fig. 16b is the same detailed view of the ground plane of the PCB 151 as in Fig. 16a, but in which the conductive surface 141 of the component 140 has been added to visualize how the slot 143 is completed by the slot section 153 printed or etched on the ground plane 151, forming a slot antenna. The contact terminals 144 are advantageously used to couple an electrical signal that excites the slot section 153 into the component 140 to excite the slot 143 contained in said component 140. For such a combined slot it is, however, also possible to excite the slot 143 in the component 140 by further feeding terminals such that the electrical signal is provided from the excited slot 143 to the slot section 153 through the contact terminals 144 and the accepting pads 154.

In some embodiments it will be preferred not to have electronic components or modules mounted on the PCB 121 and connected to its ground plane 151, if they are in the projection of the slot section 153.

In Fig. 17 an example of a slot-antenna component 160 according to the present invention is shown which includes a conductive surface 161, in which a slot 163 has been created, a dielectric substrate 162, four grounding terminals 165 and feeding means comprising a feeding terminal 164. Here Fig. 17a shows a perspective bottom view of the slot-antenna component 160 and Fig. 17b a top view of the component 160 in which the dielectric substrate 162 has been removed to observe the slot 163 in the conductive surface 161 of the component 160 and the contact terminals 164, 165.

The slot-antenna component 160 of Fig. 17 has a feeding terminal 164 provided on or close to a short edge of the conducting surface 161 or the component 160.

In the embodiment of Fig. 17 the component 160 comprises four grounding terminals 165 and a feeding terminal 164. As it can be observed in Fig. 17b, a

grounding terminal 165 is located close to each one of the four corners of the component 160. The feeding terminal 164 is located on the right-hand-side (short edge) of said component 160 between two grounding terminals 165a and 165b. Such an embodiment is advantageous as it reduces the count of grounding terminals 165 compared to the embodiment in Fig. 12, yet achieving the same grounding effect.

Another aspect of the invention refers to the feeding means used to excite the slot 113, 143, 163, 204 included in the SMT component 110, 140, 160, 200.

A slot-antenna component can be excited in an unbalanced mode or in a balanced mode. When a slot-antenna component is excited in an unbalanced manner, an unbalanced voltage is applied to the two opposite edges of the slot created in a conductive surface of the component, or to the two opposite edges of a slot section created in the ground plane of the PCB. A first edge is connected to a positive potential (referenced to a ground potential) and a second edge is connected to said ground potential. When a slot-antenna component is excited in a balanced manner, a balanced voltage is applied to the two opposite edges of the slot created in a conductive surface of the component, or to the two opposite edges of a slot section created in the ground plane of the PCB. A first edge is connected to a positive potential (referenced to a ground potential) and a second edge is connected to a negative potential (referenced to a ground potential) of the substantially same amplitude as said positive potential.

In some embodiments, such as for instance but not limited to the examples of Figures 12 and 17, the feeding means of the slot-antenna component 110, 160 comprise a feeding contact 114, 164 and a conductive strip 118, 168. Said conductive strip 118, 168 can be advantageously printed or etched on the same conductive surface 111, 161 as the slot 113, 163, thus making the feeding means coplanar with the slot 113, 163. The conductive strip 118, 168 connects the feeding terminal 114, 164 with the edge of slot 113, 163 that is farther from the contact terminal 114, 164 in region 119, 169 along the slot 113, 163. In the examples of Fig. 12 and 17 the connection of the conductive strip 118, 168 with the edge of slot 113,

163 that is farther from the contact terminal 114, 164 occurs at a substantially right angle (i.e., an angle of approximately 90°), however said connection could also occur at angles smaller or larger than 90°.

In said region 119, 169, the edge of the slot 113, 163 that is closer to the feeding terminal 114, 164 is interrupted, so that the conductive strip 118, 168 can cross the slot 113, 163 reaching the farther edge of said slot 113, 163. A clearance region 120, 170 is created at both sides of the conductive strip 118, 168 and the feeding terminal 114, 164. The width of the clearance region 120, 170 does not need to be necessarily the same on both sides of the conductive strip 118, 168 and the feeding terminal 114, 164 (d_1 and d_2 do not need to be the same), although in some embodiments d_1 and d_2 will be substantially equal. The input impedance of the slot antenna can be appropriately selected by means of the distance of the region 119, 169 to an end of slot 117, 167, the width of the conductive strip 118, 168 and the widths d_1 and d_2 of the clearance region 120, 170 on each side of the conductive strip 118, 168 and the feeding terminal 114, 164.

In certain examples, the widths d_1 and d_2 will be substantially equal. In some cases, the width of the conductive strip 118, 168 and the widths d_1 and d_2 can be advantageously selected as to form a coplanar transmission line. The width of the conductive strip 118, 168 and the widths d_1 and d_2 will be preferably smaller than a maximum width. Some possible values for said maximum width comprise 1/2400, 1/1200, 1/800, 1/600, 1/480, 1/400, 1/300, 1/240, 1/200, 1/150 and 1/120 of a free-space operating wavelength of the slot antenna.

In some cases, it will be advantageous to place a grounding terminal 115e, 115a, 165a, 165b at each side of the feeding terminal 114, 164. In other examples, the feeding terminal 114, 164 might not be coplanar with the slot 113, 163, making it necessary to couple a feeding signal from the feeding terminal 114, 164 to the conductive strip 118, 168 either by direct contact (such as for instance by means of a via hole), or by electromagnetic coupling (either capacitive or inductive). Capacitive (or inductive) coupling can be preferred in some cases to compensate for an

inductive (or capacitive) component of the input impedance of the slot antenna, without having to use external circuit elements such as capacitors or inductors.

Figures 12 and 17 show two examples of slot-antenna components 110, 160 in which the slot antenna is excited in an unbalanced manner. In some other examples, a slot-antenna component could be excited in a balanced manner by including a first feeding terminal to provide a positive potential (referenced to a ground potential) and a second feeding terminal to provide a negative potential (referenced to said ground potential). In some cases, the component can also include a third feeding terminal to provide said ground potential.

In other embodiments, such as for instance but not limited to the example of Figures 15, the feeding means of the slot-antenna component 140 comprises two contact terminals 144a, 144b that are used for feeding purposes of slot 143 created in the conductive surface 141 inside the component 140. The said contact terminals 144a, 144b couple the electric signal that excites the slot section 153 printed or etched on the ground plane of the PCB 151 with the slot 143. The slot antenna formed by the combination of the slot 143 and the slot section 153 can be excited by means of a balanced or an unbalanced electrical signal applied at a point 158 (see Fig. 18) along said slot section 153.

Fig. 18 provides examples of how a slot antenna formed by the combination of the slot-antenna component of Fig. 15 and the slot section on the PCB of Fig. 16 can be excited with an RF feeding signal.

Fig. 18a shows an example of unbalanced feeding of the slot antenna. An RF generator 171 provides a positive potential **V** (referenced to a ground potential **0**). Said positive potential **V** is applied to the left-hand-side edge of the slot section 153 in region 158. Said reference ground potential **0** is then applied to the opposite edge (the right-hand-side edge in this example) of the slot section 153 in region 158.

Fig. 18b shows an example of balanced feeding of the slot antenna. An RF generator 172 provides a positive potential **+V** (referenced to a ground potential **0**)

and a negative potential –V (referenced to the same ground potential 0), with approximately the same amplitude as said positive potential +V. Said positive potential +V is applied to the left-hand-side edge of the slot section 153 in region 158, while said negative potential –V is applied to the right-hand-side edge of the slot section 153 in region 158.

Fig. 19 provides examples showing how a slot antenna formed by the combination of the slot-antenna component 140 of Fig. 15 and the slot section 153 on the PCB of Fig. 16 can be excited in an unbalanced manner by coupling an electrical signal from an unbalanced transmission line with a coplanar transmission line (Fig. 19a), a coaxial transmission line (Fig. 19b) or a microstrip transmission line (Fig. 19c).

Fig. 19 represents different examples in which a slot antenna formed by the combination of the slot 143 contained in the component 140 and the slot section 153 printed or etched on the ground plane of the PCB 151 is excited in an unbalanced manner.

In the case of Fig. 19a, a coplanar transmission line 180 is created in the ground plane 151 of the PCB 121. Said coplanar transmission line 180 comprises a central conductive strip 181 and a region of clearance of ground plane 182 to each side of the conductive strip 181. The coplanar transmission line 181 excites the slot section 153 in region 158. In said region 158 one edge of the slot section 153 is interrupted, so that the conductive strip 181 can cross the slot section 153 reaching the opposite edge of said slot section 153. The width of the conductive strip 181 and the width d of the clearance region 182 on each side of the conductive strip 181 can be selected to provide a coplanar transmission line with the appropriate characteristic impedance required in each application.

The example in Fig. 19b shows coaxial transmission line 184 being used to excite the slot antenna. The core 183 of the coaxial transmission line 184 contacts an edge of the slot section 153 in region 158, while the outer conductor of the coaxial transmission line 185 contacts the opposite edge of the slot section 153 in region 185.

A further example is provided in Fig. 19c, in which a microstrip transmission line 186 is used. The microstrip transmission line 186 comprises a conductive strip 187 placed substantially parallel above the ground plane of the PCB 151 on which the slot section 153 is printed or etched. Said strip 187 crosses above the slot section 153 in region 158. A via hole 188 at the end of the conductive strip 187 is used to connect said conductive strip 187 with the last edge of the slot section 153 crossed by the conductive strip 187.

Examples of slot-antenna components comprising more than one conductive surfaces are shown in Fig. 20. Here in the conductive surfaces a slot, or a portion of slot, has been created. Fig. 20a provides an example of a slot-antenna component 190 comprising a first conducting surface 191 containing a first slot portion 193, and a second conducting surface 192 containing a second and a third slot portions 194, 195. The first conductive surface 191 is connected to the second conductive surface 192 by means of via holes 196, 197, 198, 199 to combine all the slot portions 193, 194, 195 into a single slot antenna. In Fig. 20b the same items as in Fig. 20a are shown, however the first and second conductive surfaces 191 and 192 are spaced apart in order to visualize more clearly the different slots and surfaces.

Fig. 20c shows an example of a slot-antenna component 200 comprising a first conducting surface 201 containing a first slot portion 203, and a second conducting surface 202 containing a second slot portion 204, wherein there is no electrical connection between the said first and second conductive surfaces 201, 202, so that one slot portion acts as a parasitic element.

In Fig. 20d the two surfaces 201 and 202 are more separated in order to visualize the details of the two surfaces more clearly.

As mentioned above in some other embodiments, a slot-antenna component may comprise more than one conductive surface in which a slot is created. For instance, Fig. 20a shows a perspective top view of an example in which a slot-antenna component 190 comprises a first conductive surface 191 on the upper side of a

dielectric substrate (not shown in Fig. 20a), and a second conductive surface 192 on the bottom side of said dielectric substrate. In this example, and without any limiting purpose, a first slot portion 193 is created in the first conductive surface 191, while a second slot portion 194 and a third slot portion 195 are contained in the second conductive surface 192. The first slot portion 193 is connected to the second slot portion 194 by means of two via holes 196, 197, and to the third slot portion 195 by means of other two via holes 198, 199. The via hole pairs 196, 197 and 198, 199 behave as the two edges of a vertical slot segment that allow to couple the electrical signal from one slot portion in a conductive surface to another slot portion in a different conductive surface, forming a single slot antenna. The second conductive surface 192 comprises one feeding terminal and four grounding terminals arranged in a similar way as in the example of Fig. 17.

As can be seen in Fig. 20 a slot longer than the one of e. g. Fig. 17 can be provided, however without increasing the required footprint area on the PCB due to the multiple surfaces of the antenna component.

In other cases it can be advantageous not to have electrical continuity between a slot portion created in a first conducting surface and another slot portion created in a second conductive surface, having thus an electrically driven slot portion and a parasitic slot portion. Fig. 20c and Fig. 20d represent a slot-antenna component 200 comprising a first conductive surface 201 on the upper side of a dielectric substrate (not shown in Fig. 20c), and a second conductive surface 202 on the bottom side of said dielectric substrate. Said first conductive surface 201 includes a first slot portion 203, while said second conductive surface 202 includes a second slot portion 204. Said first and second slot portions 203, 204 are not in electrical contact. The second conductive surface 202 comprises feeding means to feed said second slot portion 204, and also four grounding terminals arranged in a similar way as in the example of Fig. 17. Thus, the first slot portion 203 acts as a parasitic element.

An example of a wireless (e.g. handheld or portable) device comprising two slot-antenna components arranged on the PCB of said device is shown in Fig. 21. The two slot-antenna components are oriented along substantially orthogonal directions

in order to have a slot antenna radiating with a polarization substantially orthogonal to the polarization of the other slot antenna.

Fig. 21 represents a wireless handheld or portable device 210 that comprises a first slot-antenna component 211 and a second slot-antenna component 212 mounted on a substantially rectangular PCB 213. The first slot-antenna component 211 is mounted substantially close to the top edge of the PCB 213 in such a way that the longer dimension of said first component 211 is substantially aligned with the top longer edge of the PCB 213. The second slot-antenna component 212 is placed substantially close to the left edge of the PCB 213 in such a way that the longer dimension of said second component 212 is substantially aligned with the left shorter edge of the PCB 213. In other words, the longer dimension of the first slot-antenna component 211 and that of the second slot-antenna component 212 are aligned along substantially orthogonal directions, which is advantageous in some embodiments in order to excite in the first slot-antenna component 211 a resonant mode substantially orthogonal to the resonant mode of the second slot-antenna component 212. Such an arrangement of a first slot-antenna component 211 and a second slot-antenna component 212 can be advantageously used to increase the isolation between two antennas in a wireless handheld or portable device and/or to implement an antenna diversity system.

In some embodiments the slot-antenna component 110, 140, 160, 190, 200 has advantageously a rectangular shape, while in others it is substantially square. In certain cases, the length **L** of the component 110, 140, 160, 190, 200 divided by a free-space operating wavelength of the slot antenna will be preferably smaller than, or approximately equal to, at least one of the following fractions: 1/5, 1/8, 1/10, 1/12, 1/13, 1/14, 1/15, 1/16, 1/18 or 1/20. In the same way, for some embodiments the width **W** of the component 110, 140, 160, 190, 200 divided by a free-space operating wavelength of the slot antenna will be smaller than, or approximately equal to, at least one of the following fractions: 1/10, 1/15, 1/18, 1/20, 1/21, 1/22, 1/23, 1/24, 1/25 or 1/30. In some other instances, it will be advantageous that the sum of the length **L** and the width **W** of the slot-antenna component 110, 140, 160, 190, 200 be smaller than 1/2 of the free-space operating wavelength, or even smaller

than 1/4 of the free-space operating wavelength. As far as height **H** is concerned, the slot-antenna component 110, 140, 160, 190, 200 features very low profile. In some instances the height **H** of the component 110, 140, 160, 190, 200 is less than a fortieth (1/40), a sixtieth (1/60) or even a one hundred twentieth (1/120) of a free-space operating wavelength of the slot antenna.

In some embodiments according to the present invention which comprise a slot 143 included in a component 140 and a slot section 153 printed or etched in the ground plane of a PCB 151, the unfolded length of the slot section 153 will be less than 50%, 40%, 30%, 25%, 20%, 18%, 16%, 14%, 12%, 10% or even 5% of the unfolded length of the combination of the slot 143 and the slot section 153.

Moreover, in some cases it will be advantageous that a slot-antenna component 140 together with a slot section 153 printed or etched on the ground plane of the PCB 151 fit within a rectangular area 156 (indicated in dotted line in Fig. 16a) of length **L'** and width **W'**, wherein the sum of **L'** and **W'** is less than, or approximately equal to, 25%, 22.5%, 20%, 17.5%, 15%, 12.5%, or even 10% of a free-space operating wavelength of the slot antenna.

In the example of Fig. 12, the slot 113 has a first end 116 that intersects the perimeter of the conductive surface 111. That is, the slot 113 is open-ended at said first end 116. Furthermore, the slot 113 has a second end 117 that does not intersect the perimeter of the conductive surface 111 (i.e., it is closed-ended).

In the case of Fig. 15, the slot 143 features a first end 146 and a second end 147 both intersecting the perimeter of the conducting surface 141. While said first end 146 is open-ended, the second end 147 is coupled to the slot section 153 of the ground plane of the PCB 151, as it can be seen in Fig. 16. The slot section 153 printed or etched on the ground plane 151 comprises a closed end 157. Therefore, the combination of the slot 143 with the slot section 153 forms a slot antenna with an open end 146 and a closed end 157.

In some preferred cases, the unfolded length of the slot antenna formed by a slot 113, 163 or by the combination of a slot 143 and a slot section on the ground plane of the PCB 153, will be approximately a quarter of an operating wavelength of the slot antenna. In some other cases, the unfolded length of the slot 113, 163, or the combination of the slot 143 and the slot section on the ground plane of the PCB 153, will be approximately three times, or approximately five times, or approximately another odd integer number of times, the length of one quarter of an operating wavelength of the slot antenna.

In other embodiments, a first end 116, 166 and a second end 117, 167 of the slot 113, 163 might both intersect the perimeter of the conductive layer 111, 161 of the slot-antenna component 110, 160. Yet in some other embodiments, both the first end 116, 166 and the second end 117, 167 of the slot 113, 163 might be closed-ended. In other embodiments, a first end 146 of the slot 143 intersects the perimeter of the conductive layer 141 of the slot-antenna component 140, while at the same time the end 157 of the slot section 153 intersects the perimeter of the ground plane 151.

In some embodiments in which a first end 116, 146, 166 and a second end 117, 167, or the end of slot section 157, are either both open-ended or both closed-ended, it might be advantageous that the unfolded length of the slot antenna formed by a slot 113, 163, or by the combination of a slot 143 and a slot section on the ground plane of the PCB 153, be approximately twice, or approximately four times, or approximately another even integer number of times, the length of one quarter of an operating wavelength of the slot antenna.

In some other embodiments, an open end of the slot 116, 146, 166 included in the slot-antenna component 110, 140, 160 can be coupled to a slot section printed or etched on the ground plane of a PCB. In that case, a slot-antenna component 110, 140, 160 should include an additional contact terminal on each edge of the slot 113, 143, 163 near said open end 116, 146, 166 to allow the coupling of an electrical signal from the slot 113, 143, 163 to a slot section created in the ground plane of the PCB. For example, in the embodiments of Fig. 12 and 17, a slot antenna would be

formed by the combination of the slot 113, 163 included in the component 110, 160, and a slot section created in the ground plane of the PCB and coupled to the open-ended end 116, 166. Similarly, in the example of Fig. 15 a slot antenna would be formed by the combination of the slot section 153 printed or etched in the ground plane of the PCB 151, the slot 143 included in the component 140, and an additional slot section created also in the ground plane of the PCB and coupled to the open end of the slot 146.

The shape of a slot 113, 143, 163, 193, 194, 195, 203, 204 inside a slot-antenna component 110, 140, 160, 190, 200 and/or a slot section on the PCB 153 can comprise straight and curved segments, not necessarily all segments being of the same length. In the same way, the separation between the conductive edges of each segment of the slot 113, 143, 163, 193, 194, 195, 203, 204, and/or a slot section on the PCB 153, does not have to be the same for all segments, nor constant for any given segment (i.e., any segment of the slot 113, 143, 163, 193, 194, 195, 203, 204 or the slot section on the PCB 153 can be tapered).

Furthermore, it will be advantageous in some cases that the separation between the two edges of a slot 113, 143, 163, 193, 194, 195, 203, 204 and/or a slot section on the PCB 153 be within a range from approximately the 0.08% of the free-space operating wavelength to approximately the 8% of the free-space operating wavelength, including any subinterval of said range. Some possible upper bounds for a subinterval of said range include: 4%, 2%, 1% or 0.5%. Some possible lower bounds for a subinterval of said range include: 0.12%, 0.16%, 0.20% or 0.24%.

In some examples, the slot 113, 143, 163, 193, 194, 195, 203, 204 , and/or the slot section on the PCB 153 might have one, two, three, or more bends. In general, as the number of bends in the slot 113, 143, 163, 193, 194, 195, 203, 204 and/or in the slot section on the PCB 153 increases, the shape of the slot 113, 143, 163, 193, 194, 195, 203, 204 and/or the slot section on the PCB 153 becomes more and more convoluted, leading to a higher degree of miniaturization of the resulting slot antenna.

For miniaturization purposes, at least a portion of the curve defining the slot 113, 143, 163, 193, 194, 195, 203, 204 or the slot section on the PCB 153 will advantageously be a space-filling curve, a box-counting curve, a grid-dimension curve, or a fractal based curve. The curve defining said slot 113, 143, 163, 193, 194, 195, 203, 204 and/or said slot section 153 might take the form of a single curve, or might branch-out in two or more curves, which at the same time in some embodiments will be also of the space-filling, box-counting, grid-dimension, or fractal kinds. Additionally, in some embodiments a part of the curve will be coupled either through direct contact or electromagnetic coupling to a conducting polygonal or multilevel surface.

One aspect of the present invention relates to the connection of a slot-antenna component 110, 140, 160 to the ground plane 131, 151 of the PCB on which it is mounted in order to ensure a good electrical continuity between the conductive surface 111, 141, 161 contained in the component 110, 140, 160 and said ground plane 131, 151.

In the example of Fig. 12b, the component 110 has five grounding terminals 115 and they are distributed around the extension of the conductive surface 111 in order to ensure a good electrical continuity with the ground plane 131. Two grounding terminals 115a, 115b are located close to the right-hand-side edge of component 110 opposite to other two grounding terminals 115c, 115d located close to the left-hand-side edge of the component 110. Moreover, grounding terminals 115a, 115b, 115c, 115d are on at least two of the four corners of component 110, specifically one on each corner.

The slot component 140 in Fig. 15b comprises three contact terminals 144a, 144b, 145 used for grounding purposes. Contact terminals 144 are placed substantially close to the right-hand-side edge of the component 140, while contact terminal 145 is located close to the left-hand-side edge of the component 140. Again, the grounding terminals are arranged in such a manner that they are substantially close to at least two of the corners of the component 140. Grounding terminal 145 extends

along one of the short edges of the component 140 being at the same time substantially close to two of the four corners of the component.

Furthermore, in some examples it can be advantageous to place grounding terminals at two sides of a feeding terminal and substantially close to said feeding terminal. In Fig. 12b, the slot-antenna component 110 comprises a first grounding terminal 115e on the left-hand-side of the feeding terminal 114, and a second grounding terminal 115a on the right-hand-side of said feeding terminal 114.

In some other embodiments, in order to guarantee good grounding of the component 110, 140, 160 it will be advantageous to have one, two, three, four, five, six, or even more grounding terminals 115, 144, 145, 165 in the slot-antenna component 110, 140, 160.

In some cases, a slot antenna comprising a slot-antenna component 110, 140, 160 will be advantageously excited by applying a voltage difference between the opposite conductive edges of a slot 113, 163, or between the opposite conductive edges of a slot section 153, at a particular point 119, 158, 169 along the geometry of the slot 113, 163, or slot section 153. In some embodiments, said point 119, 158, 169 will be closer to a closed end of the slot 117, 167, or a closed end 157 of a slot section 153, than to an open end of the slot 116, 146, 166. In certain examples, the distance between said point 119, 158, 169 and a closed end 117, 167 of the slot 113, 163, or a closed end 157 of a slot section 153, will be less than, or equal to, 0.2%, 0.4%, 0.8%, 1.2% 1.6%, 2.5%, 3.3%, 4%, 8%, 10% or 15% of a free-space operating wavelength of the slot antenna.

A further aspect of the present invention relates to the control on the electrical parameters of the slot-antenna component by appropriately selecting the orientation and placement of the component on a PCB. The polarization of the radiating mode of the slot-antenna component 110, 140, 160, 190, 200 mounted as depicted in Fig. 13c is substantially orthogonal to the radiating mode of the same slot-antenna component 110, 140, 160, 190, 200 mounted as depicted in Fig. 13a. Moreover, when the slot-antenna component 110, 140, 160, 190, 200 is

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 August 2005 (18.08.2005)

PCT

(10) International Publication Number
WO 2005/076409 A1

(51) International Patent Classification[7]: H01Q 21/30, 1/38, 9/40, 1/22, G06F 1/16

(21) International Application Number: PCT/EP2005/000879

(22) International Filing Date: 28 January 2005 (28.01.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/540,448 30 January 2004 (30.01.2004) US

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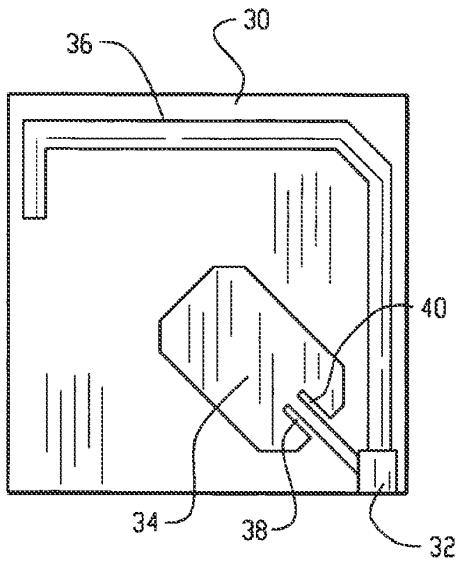
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: MULTI-BAND MONOPOLE ANTENNAS FOR MOBILE NETWORK COMMUNICATIONS DEVICES



(57) Abstract: Multiband monopole antennas are disclosed. The antennas disclosed can include a substrate for mounting conductors, one or more conductors for receiving networking signals mainly in a first frequency band, and one or more conductors for receiving networking signals mainly in a second frequency band. The conductors can have a polygonal shape or the conductors can have a linear, space-filling, or grid dimension shape. The conductors can be connected at a feed point. One or more antenna can be incorporated into a single printed circuit board. When multiple antennas are used with the same printed circuit board, the conducting material of the printed circuit board located between the antenna attachment points can be interrupted to improve the isolation of each antenna.

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MULTI-BAND MONOPOLE ANTENNAS FOR MOBILE NETWORK COMMUNICATIONS DEVICES

Introduction

This invention relates generally to the field of multi-band monopole antennas. More specifically, multi-band monopole antennas are provided that are particularly well-suited for use in mobile network communications devices, such as PCMCIA wireless cards, electronic devices with integrated WI-FI and WiMAX modules, compact flash wireless cards, wireless USB/UART dongles, and other wireless networking devices.

BACKGROUND

Multi-band antenna structures for use in a mobile network communications device are known in this art. In known wireless PCMCIA cards, for example, two dual-band antennas are typically used. The two antennas in a PCMCIA card, for example, are used with a diversity system in which the signal received from each antenna is compared and the best signal at any given time is used. A diversity system is particularly useful for indoor and multipath reception.

Summary

Multiband monopole antennas are disclosed. The antennas disclosed can include a substrate for mounting conductors, a first conductor for receiving networking signals mainly in a first frequency band, and a second conductor for receiving networking signals mainly in a second frequency band. The first conductor can have a polygonal shape with an aspect ratio of length to width of less than about 5

to about 1. The second conductor can be linear, space-filling, or grid dimension. The first and second conductors can be connected at a feeding point.

The antennas disclosed can also include a substrate for mounting conductors, first and second conductors for receiving networking signals mainly in a first frequency band, and third and fourth conductors for receiving networking signals mainly in a second frequency band. The first and second conductors can be symmetrical polygonal shapes that have an aspect ratio of length to width of less than about 5 to about 1. The third and fourth conductors can be symmetrical linear, space-filling, or grid dimension shapes. The first and second conductors can be symmetrically oriented with respect to each other about a central axis on the antenna substrate and the third and fourth conductors can be symmetrically oriented with respect to each other about the central axis on the antenna substrate. The first, second, third and fourth conductors can be connected at a feeding point.

The antennas can be formed on simple, readily available circuit board materials as separate units or formed directly onto a printed circuit board. Two or more of the disclosed antennas can be used on a single printed circuit board. When two or more antennas are used with the same printed circuit board, the conducting material of the printed circuit board located between the antenna attachment points can be interrupted to improve the isolation of each antenna.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a top view of a multi-band monopole antenna for use in mobile network communications devices;

Fig. 2 shows a top view of another multi-band monopole antenna for use in mobile network communications devices;

Fig. 3 shows a top view of a non-symmetrical multibranch monopole antenna for use in mobile network communications devices;

Fig. 4 shows a top view of a symmetrical multibranch monopole antenna for use in mobile network communications devices;

Fig. 5 shows one example of a space-filling curve;

Figs. 6-9 illustrate an exemplary two-dimensional antenna geometry forming a grid dimension curve;

Fig. 10 shows a suggested cardbus PCB layout for use with the antenna shown in Fig. 4; and

Fig. 11 shows another suggested cardbus PCB layout for use with the antenna shown in Fig. 4.

DETAILED DESCRIPTION

Referring now to the drawing figures, Fig. 1 and Fig. 2 are top views of two exemplary multi-band monopole antennas for use in mobile network communications devices. The antennas of Fig. 1 and Fig. 2 include substrates (10, 20) and multibranch monopole conductors with the branches being connected at common points called feeding points (12, 22). The antenna substrates of Fig. 1 and Fig. 2 can, for example, be a 10 mm × 10 mm × 0.8 mm circuit board with a copper base conductor. The number of branches of a monopole antenna is directly related to the number of frequency bands or groups of bands that can be received. The antennas of Fig. 1 and Fig. 2 have two branches and are, thus, capable of receiving two different frequency bands. The branches of the antennas of Fig. 1 and Fig. 2 are non-symmetrical with the longer branch (14, 24) receiving a lower frequency band and the shorter branch (16, 26) receiving a higher frequency band. The length of the branches can be configured to receive signals specified in networking standards such as the 802.11bg/Bluetooth standard (2.4-2.5 GHz) and the 802.11a band (4.9-5.875 GHz). Thus, the antennas of both Fig. 1 and Fig. 2 can

be configured, for example, to receive both 802.11bg band frequencies on the longer branch (14, 24) and 802.11a band frequencies on the shorter branch (16, 26). Coupling between branches in multibranch antennas is possible and such coupling can be taken into account during the design of the antenna. Further, services other than networking broadcast on these frequencies and the antennas disclosed herein can be used with those services as well.

Another multi-band monopole antenna design is shown in Fig. 3. The antenna of Fig. 3 is a non-symmetrical multibranch monopole. The antenna of Fig. 3 includes a substrate 30, a feeding point 32, and two conductor branches (34, 36). The shorter branch 34 is a polygonal monopole with notches (38, 40). The polygonal monopole could also have a multilevel shape such as that described in U.S. Patent Application Publication No. US 2002/0140615 A1, which is hereby incorporated by reference. The aspect ratio, i.e., the length compared to the width, of the shorter branch 34 of the polygonal monopole as depicted in Fig. 3 is about 3 to about 2. Preferably the aspect ratio is less than about 5 to about 1, more preferably the aspect ratio is less than about 3 to about 1, and even more preferably the aspect ratio is less than about 2 to about 1. The notches (38, 40) contribute to the antenna impedance match. One or more notches can be used, the length of each notch can vary, and, if more than one notch is used, the notches may be different lengths. A polygonal monopole can also have no notches. The longer branch 36 receives a lower frequency band and the shorter branch 34 receives a higher frequency band. The longer 36 and shorter 34 branches can be configured to receive network standard signals as discussed above with the antennas of Fig. 1 and Fig. 2.

Non-symmetrical antennas like the one shown in Fig. 3 are often designed for a specific printed circuit board (PCB) and, thus, are locked into a specific orientation on the PCB because the performance of the antenna can change with changes in the position, orientation, or identity of nearby circuitry. Symmetrical antennas on the other hand usually offer greater flexibility in terms of PCB placement be-

cause they are not as effected by changes in position, orientation, or identity of nearby circuitry.

Another multi-band monopole antenna is shown in Fig. 4. The antenna shown in Fig. 4 is a symmetrical multibranch monopole antenna. The antenna of Fig. 4 includes a substrate 50, a feeding point 52, and four conductor branches (54, 56, 58, 60). Each conducting branch has an opposing mirror image conducting branch that is symmetrical about a plane 61 that roughly divides the substrate 50 in half from top to bottom. The shorter branches (54, 56) are mirror images of each other with respect to plane 61 and the longer branches (58, 60) are mirror images of each other with respect to plane 61. The shorter branches (54, 56) are polygonal monopoles with notches as discussed above with respect to the antenna of Fig. 3. The longer branches (58, 60) receive a lower frequency band and the shorter branches (54, 56) receive a higher frequency band. The longer branches can be linear, space-filing, or grid dimension curves. The longer (58, 60) and shorter (54, 56) branches can be configured to receive network standard signals as discussed above with respect to the antennas of Fig. 1 and Fig. 2. Due to its symmetry, the antenna of Fig. 4 has greater flexibility in terms of PCB placement than the non-symmetrical antennas discussed above.

An example of a space-filling curve 62 is shown in Fig. 5. As used herein space-filling means a curve formed from a line that includes at least ten segments, with each segment forming an angle with an adjacent segment. When used in an antenna, each segment in a space-filling curve 62 should be shorter than one-tenth of the free-space operating wavelength of the antenna.

Examples of grid dimension curves are shown in Figs. 6 to 9. The grid dimension of a curve may be calculated as follows. A first grid having square cells of length L1 is positioned over the geometry of the curve, such that the grid completely covers the curve. The number of cells (N1) in the first grid that enclose at least a portion of the curve are counted. Next, a second grid having square cells of

length L2 is similarly positioned to completely cover the geometry of the curve, and the number of cells (N2) in the second grid that enclose at least a portion of the curve are counted. In addition, the first and second grids should be positioned within a minimum rectangular area enclosing the curve, such that no entire row or column on the perimeter of one of the grids fails to enclose at least a portion of the curve. The first grid should include at least twenty-five cells, and the second grid should include four times the number of cells as the first grid. Thus, the length (L2) of each square cell in the second grid should be one-half the length (L1) of each square cell in the first grid. The grid dimension (D_g) may then be calculated with the following equation:

$$D_g = -\frac{\log(N2) - \log(N1)}{\log(L2) - \log(L1)}$$

For the purposes of this application, the term grid dimension curve is used to describe a curve geometry having a grid dimension that is greater than one (1). The larger the grid dimension, the higher the degree of miniaturization that may be achieved by the grid dimension curve in terms of an antenna operating at a specific frequency or wavelength. In addition, a grid dimension curve may, in some cases, also meet the requirements of a space-filling curve, as defined above. Therefore, for the purposes of this application, a space-filling curve is one type of grid dimension curve.

Fig. 6 shows an exemplary two-dimensional antenna 64 forming a grid dimension curve with a grid dimension of approximately two (2). Fig. 7 shows the antenna 64 of Fig. 6 enclosed in a first grid 66 having thirty-two (32) square cells, each with length L1. Fig. 8 shows the same antenna 64 enclosed in a second grid 68 having one hundred twenty-eight (128) square cells, each with a length L2. The length (L1) of each square cell in the first grid 66 is twice the length (L2) of each square cell in the second grid 68 (L2 = 2 × L1). An examination of Figs. 7 and 8 reveal that at least a portion of the antenna 64 is enclosed within every square cell in both the first and second grids 66, 68. Therefore, the value of N1 in the above grid dimension (D_g) equation is thirty-two (32) (*i.e.*, the total number of cells in

the first grid 66), and the value of N2 is one hundred twenty-eight (128) (i.e., the total number of cells in the second grid 68). Using the above equation, the grid dimension of the antenna 64 may be calculated as follows:

$$D_g = -\frac{\log(128) - \log(32)}{\log(2 \times L1) - \log(L1)} = 2$$

For a more accurate calculation of the grid dimension, the number of square cells may be increased up to a maximum amount. The maximum number of cells in a grid is dependent upon the resolution of the curve. As the number of cells approaches the maximum, the grid dimension calculation becomes more accurate. If a grid having more than the maximum number of cells is selected, however, then the accuracy of the grid dimension calculation begins to decrease. In some cases, the maximum number of cells is 100, but typically, the maximum number of cells in a grid is one thousand (1000).

For example, Fig. 9 shows the same antenna 64 enclosed in a third grid 69 with five hundred twelve (512) square cells, each having a length L3. The length (L3) of the cells in the third grid 69 is one half the length (L2) of the cells in the second grid 68, shown in Fig. 8. As noted above, a portion of the antenna 64 is enclosed within every square cell in the second grid 68, thus the value of N for the second grid 68 is one hundred twenty-eight (128). An examination of Fig. 9, however, reveals that the antenna 64 is enclosed within only five hundred nine (509) of the five hundred twelve (512) cells in the third grid 69. Therefore, the value of N for the third grid 69 is five hundred nine (509). Using Figs. 8 and 9, a more accurate value for the grid dimension (D_g) of the antenna 64 may be calculated as follows:

$$D_g = -\frac{\log(509) - \log(128)}{\log(2 \times L2) - \log(L2)} \approx 1.9915$$

The performance aspects of multi-band monopole antennas can be effected by the layout of the metal in the PCB where an antenna is mounted. As discussed above, antennas can be designed to work within particular PCB environments or a PCB can be optimized to work with a particular antenna design. The specific design of the antenna shown in Fig. 3, for example, makes it particularly well-suited for use

with a cardbus PCB. To utilize the antenna shown in Fig. 3 with a cardbus PCB, two copies of the antennas shown in Fig. 3 could, for example, be mounted in the upper left corner and upper right corner of the cardbus PCB. Figs. 10 and 11 show examples of two PCBs suitable for use with the antenna of Fig. 4. In Fig. 10 and Fig. 11, two copies of the antenna of Fig. 4, for example, could be mounted in the upper left corners (80, 90) and upper right corners (82, 92). The PCBs of Fig. 10 and Fig. 11 include slots (84, 94) in the upper portion of the PCB. The slots (84, 94) provide an interruption in or absence of conducting material between antenna attachment positions. The slots (84, 94) allow the adjustment of the electrical path of the currents and fields that propagate along the conductive edge. An interruption in or absence of conducting material between antennas mounted on a PCB increases each antenna's isolation from the other antenna thereby potentially improving performance. In addition to slots, other interruptions that can be used include, but are not limited to, holes, FracPlane^{TM} ground plates (such as those described in U.S. Patent Application Publication No. US 2004/0217916 A1, which is hereby incorporated by reference), and periodic, quasi-periodic, space-filling, multi-level, and frequency selective geometries. Further, one or more interruptions can be used. Figs. 10 and 11 show examples in which separate antenna components are mounted on a PCB. When an antenna is formed as a component separate from the PCB on which it will eventually be mounted, the substrate material used to make the antenna can be simple, readily available printed circuit board material. Further, directly forming an antenna on a particular PCB is also possible. In some embodiments, the antenna is formed directly on a substrate or laminate of an integrated circuit package including other electronic or radio frequency (RF) components or semiconductor dies.

This written description uses examples to disclose the invention, including the best mode, and also to enable a person skilled in the art to make and use the invention. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples, which may be available either before or after the application filing date, are in-

tended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

Claims

1. A multi-band monopole antenna, comprising:

an antenna substrate;

a first conductor for receiving networking signals in the frequency range of about 4.9 GHz to about 5.875 GHz, said first conductor having a polygonal shape with an aspect ratio of length to width of less than about 5 to about 1;

a second conductor for receiving networking signals in the frequency range of about 2.4 GHz to about 2.5 GHz, said second conductor adopting a linear, space-filling, or grid dimension shape; and

a feeding point for connecting the first conductor and the second conductor.

2. The multi-band monopole antenna of claim 1, wherein the first conductor has one or more notches where material is removed from the polygonal shape for matching the impedance of the antenna.

3. The multi-band monopole antenna of claim 1, wherein the first conductor has an aspect ratio of less than about 3 to about 1.

4. The multi-band monopole antenna of claim 1, wherein the first conductor has an aspect ratio of less than about 2 to about 1.

5. The multi-band monopole antenna of claim 1, wherein the first conductor has an aspect ratio of about 3 to about 2.

6. The multi-band monopole antenna of claim 1, wherein the first conductor receives network signals in the 802.11a band.

7. The multi-band monopole antenna of claim 1, wherein the second conductor receives network signals in the 802.11bg band.

8. The multi-band monopole antenna of claim 1, wherein the substrate comprises a 10 mm × 10 mm × 0.8 mm circuit board with a copper base conductor.

9. A printed circuit board comprising one or more of the multi-band monopole antennas of claim 1.

10. The printed circuit board of claim 9, wherein two or more multi-band monopole antennas are used and conducting material of the printed circuit board located between the antenna attachment points is interrupted.

11. A symmetrical multi-band monopole antenna, comprising:

an antenna substrate;

first and second conductors for receiving networking signals in the frequency range of about 4.9 GHz to about 5.875 GHz, said first and second conductors having symmetrical polygonal shapes with an aspect ratio of length to width of less than about 5 to about 1;

third and fourth conductors for receiving networking signals in the frequency range of about 2.4 GHz to about 2.5 GHz, said third and fourth conductors adopting symmetrical linear, space-filling, or grid dimension shapes; and

a feeding point for connecting the first, second, third and fourth conductors,

wherein the first and second conductors are symmetrically oriented with respect to each other about a central axis on the antenna substrate and the third and fourth conductors are symmetrically oriented with respect to each other about the central axis on the antenna substrate.

12. The symmetrical multi-band monopole antenna of claim 11, wherein the first and second conductors have one or more notches where material is removed from the polygonal shape for matching the impedance of the antenna.

13. The symmetrical multi-band monopole antenna of claim 11, wherein the first and second conductors each have an aspect ratio of less than about 3 to about 1.

14. The symmetrical multi-band monopole antenna of claim 11, wherein the first and second conductors each have an aspect ratio of less than about 2 to about 1.

15. The symmetrical multi-band monopole antenna of claim 11, wherein the first and second conductors each have an aspect ratio of about 3 to about 2.

16. The symmetrical multi-band monopole antenna of claim 11, wherein the first and second conductor receives network signals in the 802.11a band.

17. The symmetrical multi-band monopole antenna of claim 11, wherein the second and third conductors receive network signals in the 802.11bg band.

18. The symmetrical multi-band monopole antenna of claim 11, wherein the substrate comprises a 10 mm × 10 mm × 0.8 mm circuit board with a copper base conductor.

19. A printed circuit board comprising one or more of the symmetrical multi-band monopole antennas of claim 11.

20. The printed circuit board of claim 9, wherein two or more symmetrical multi-band monopole antennas are used and conducting material of the printed circuit board located between the antenna attachment points is interrupted.

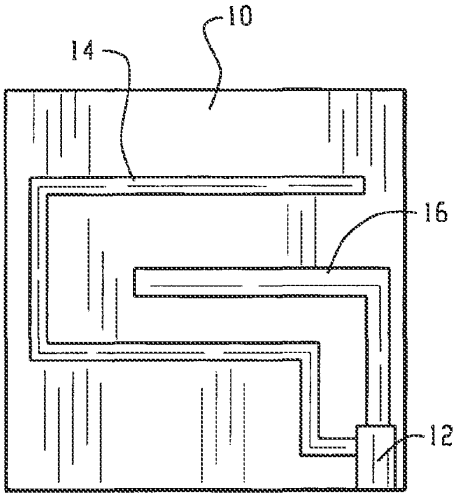


Fig. 1

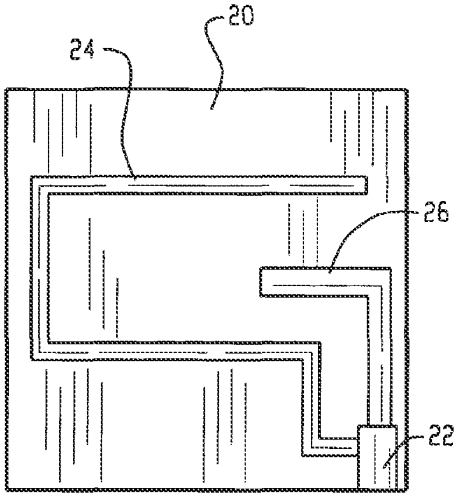


Fig. 2

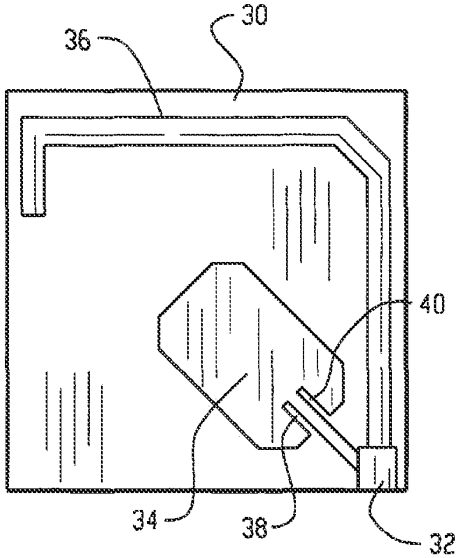


Fig. 3

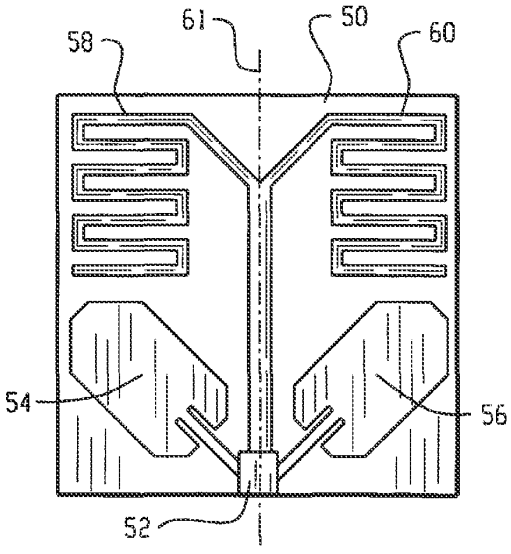


Fig. 4

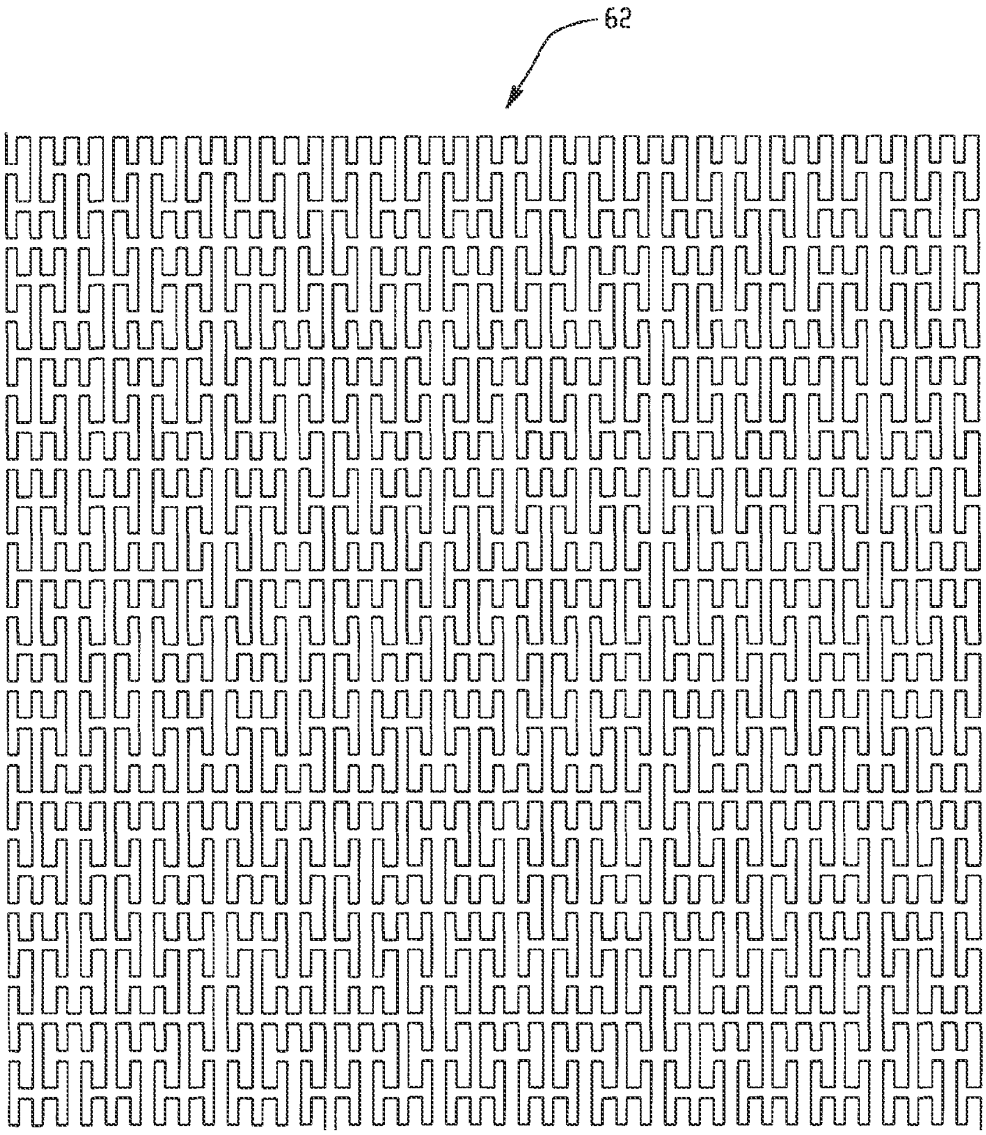


Fig. 5

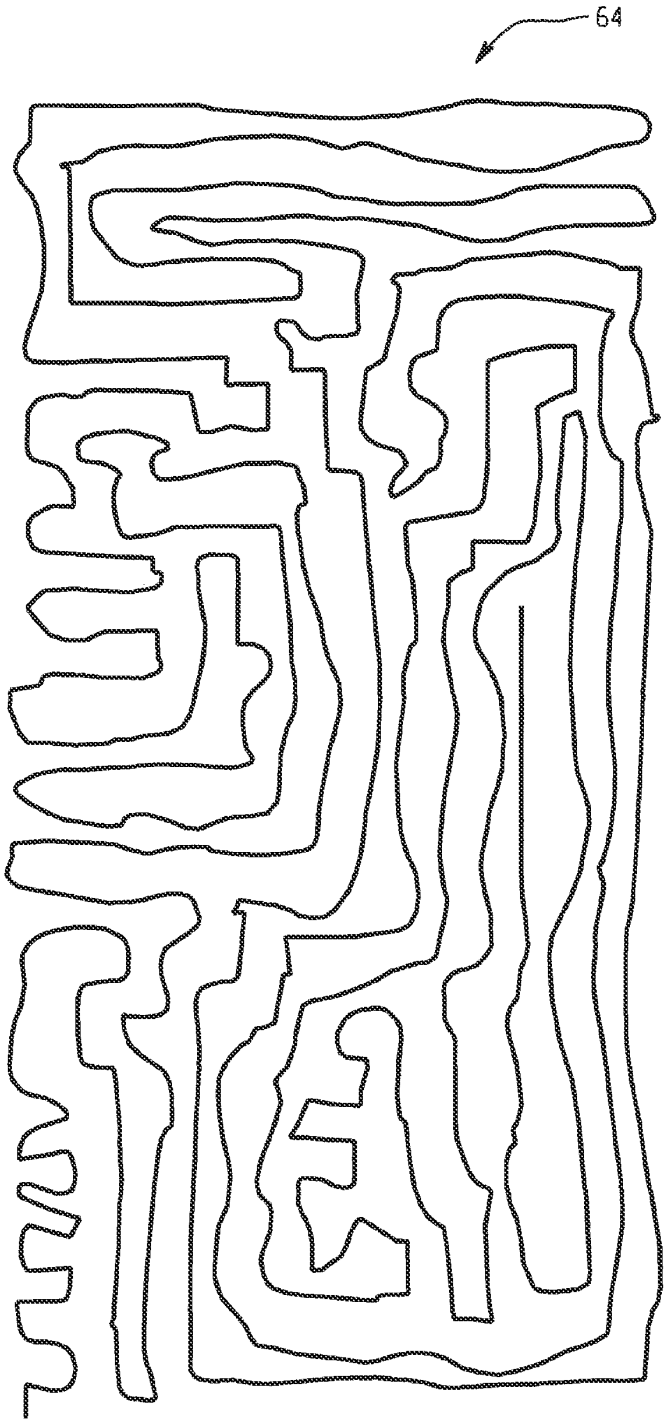


Fig. 6

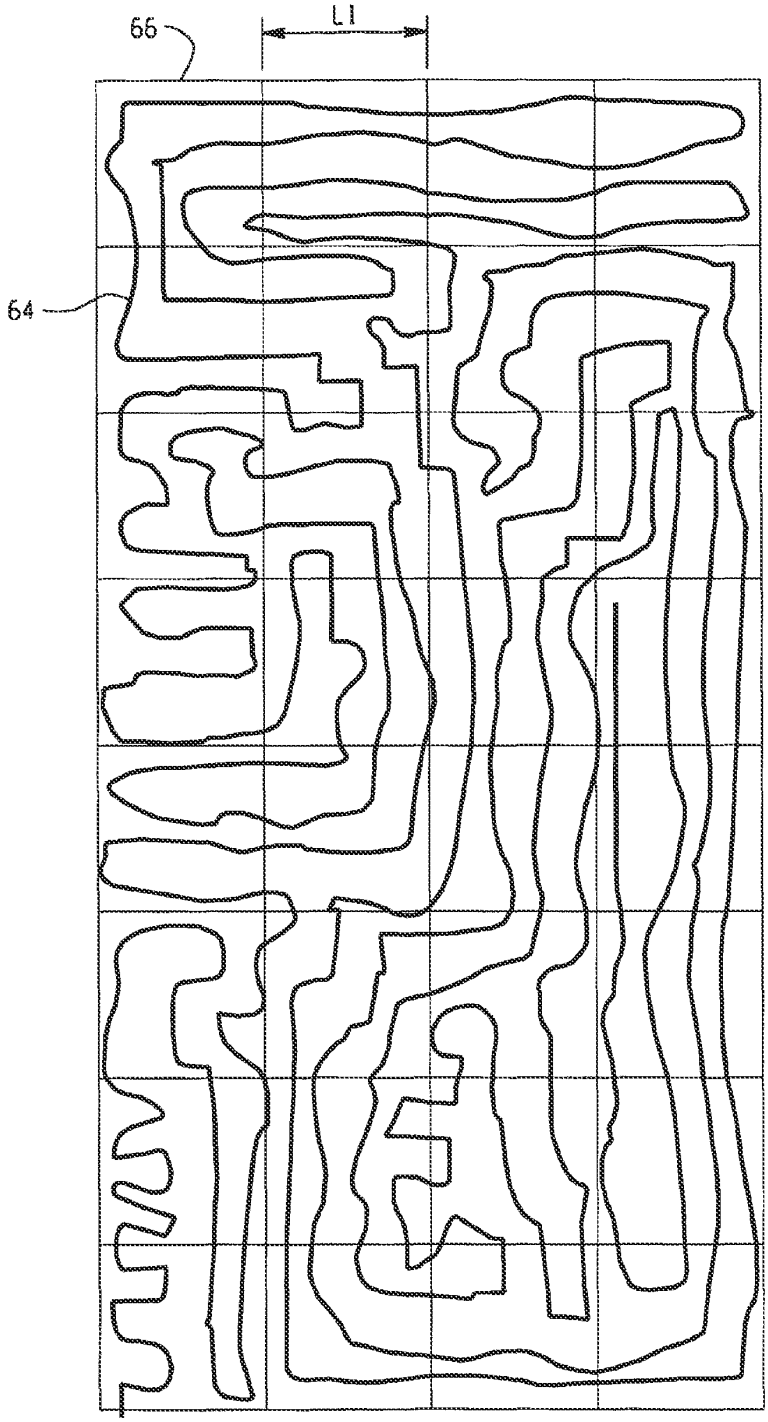


Fig. 7

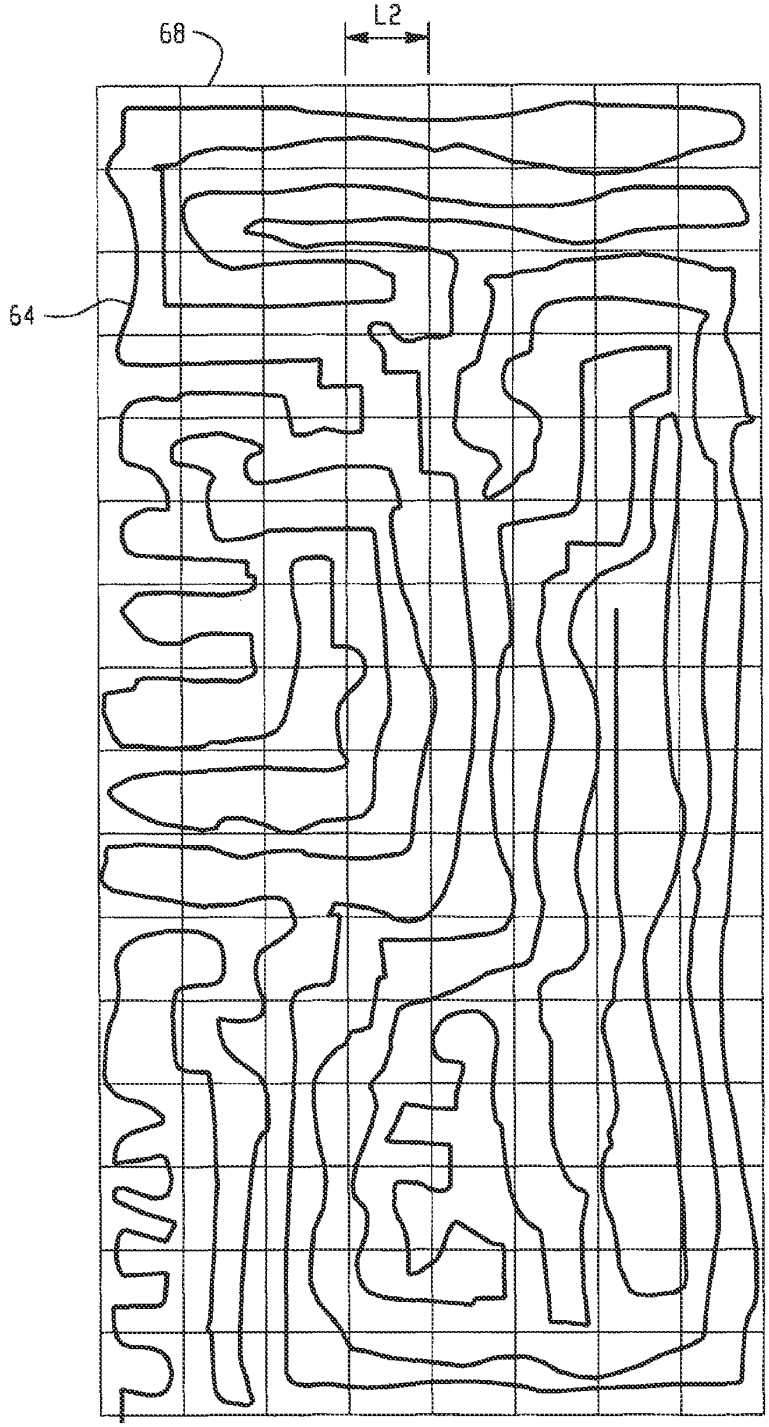


Fig. 8

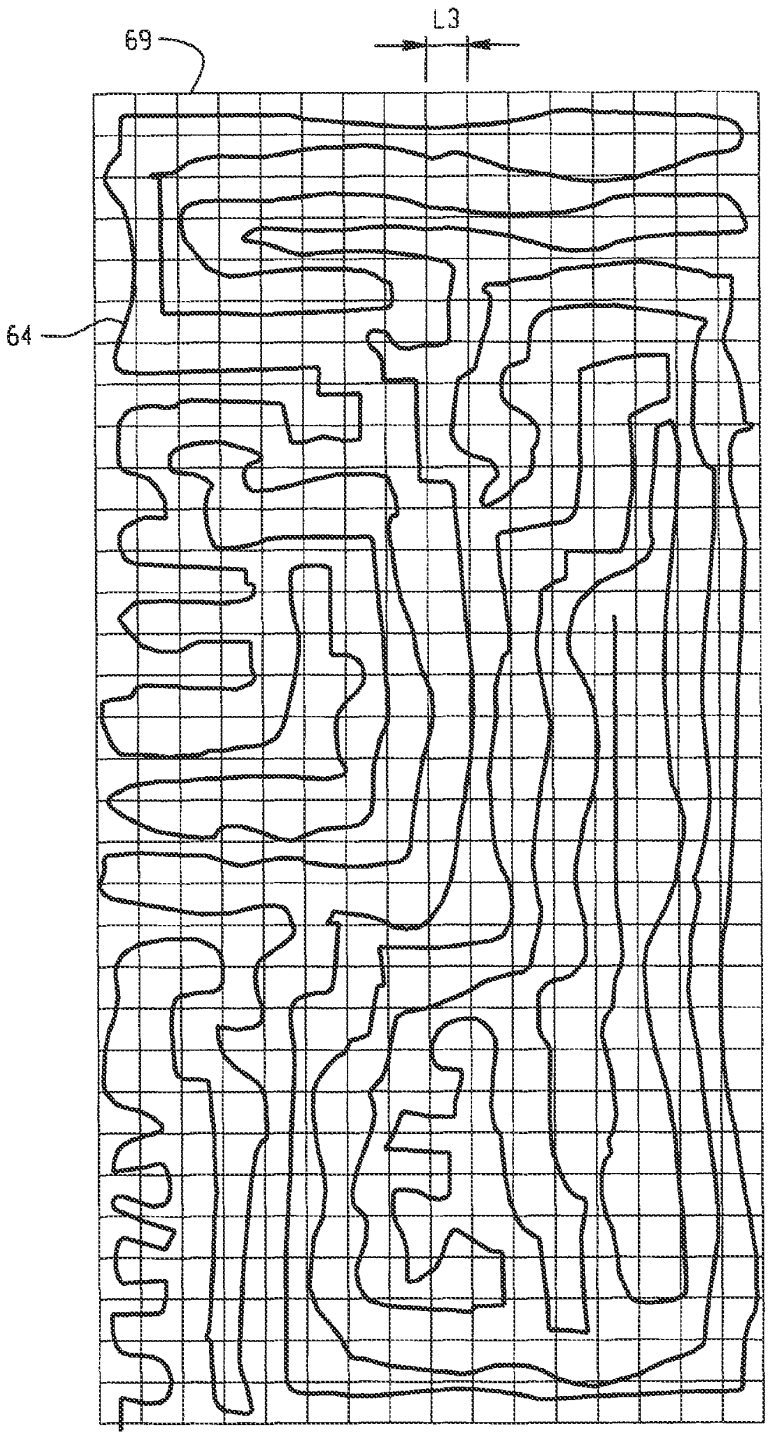


Fig. 9

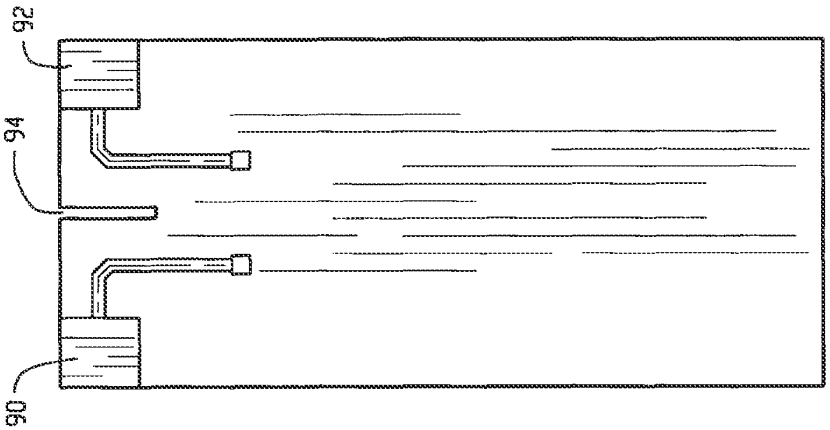


Fig. 11

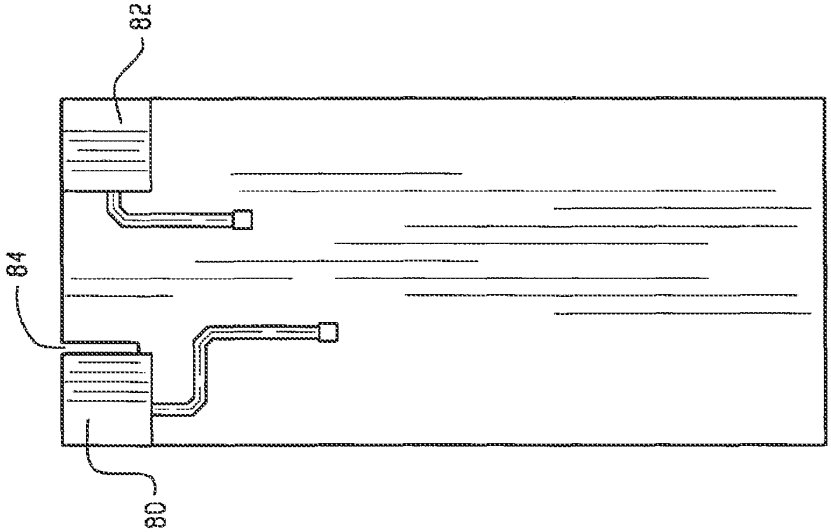


Fig. 10

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2005/000879

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q21/30 H01Q1/38 H01Q9/40 H01Q1/22 G06F1/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q G06F

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/210187 A1 (WONG KIN LU ET AL) 13 November 2003 (2003-11-13) pages 2-3; figures 1,7a,7b	1,6,7,9, 11,16, 17,19
X Y		8,18 2-5, 12-15
Y		10,20

X	PATENT ABSTRACTS OF JAPAN vol. 2003, no. 12, 5 December 2003 (2003-12-05) -& JP 2003 347828 A (SONY CORP), 5 December 2003 (2003-12-05) abstract	1
Y		10,20

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

[X] Patent family members are listed in annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 April 2005	10/05/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040. Tx. 31 651 epo nl. Fax: (+31–70) 340–3016	Ribbe, J

Form PCT/ISA/210 (second sheet) (January 2004)

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Page 272

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP2005/000879

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2003210187 A1	13-11-2003	NONE	
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		SE 0102183 A	24-09-2002
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WO 03023900 A	20-03-2003	WO 03023900 A1	20-03-2003
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Form PCT/ISA/210 (patent family annex) (January 2004)

adjacent parts of the second area on the second surface are each provided with a conductive plate or patch that is electrically isolated from the groundplane.

15. An antenna device as claimed in claim 14, wherein the conductive plates or patches on the second surface each have a slot, and wherein the feedlines pass under the dielectric elements on the first surface in such a way that each feedline crosses the slot in the respective plate or patch.

16. An antenna device as claimed in any preceding claim, wherein an additional groundplane is provided on the first area of the first surface, the additional groundplane being insulated from the feedlines.

17. An antenna device as claimed in any preceding claim, wherein the feedline diverge from each other on the first surface in the second area.

18. An antenna device as claimed in claim 17, wherein the feedlines diverge from each other at an angle of substantially 90 degrees.

19. An antenna device as claimed in claim 17, wherein the feedlines diverge from each other at an angle of less than 90 degrees.

20. An antenna device as claimed in claim 17, wherein the feedlines diverge from each other at an angle of more than 90 degrees.

21. An antenna device as claimed in any preceding claim, further comprising at least one switch and at least one additional section of feedline which can be switched in and out of one of the feedlines by the switch so as to change an operating frequency of the antenna device.

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22. An antenna device as claimed in any preceding claim, wherein at least one surface of each dielectric element is metallised or provided with a conductive coating.

23. An antenna device as claimed in claim 22, wherein the surface is a top surface.

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Page 276

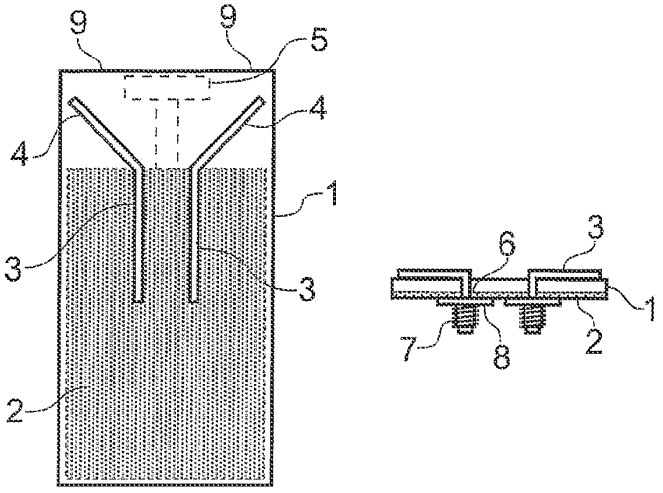


Fig. 1

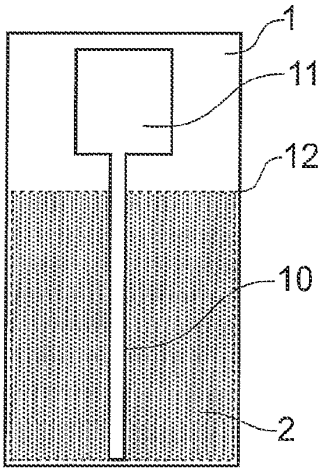


Fig. 2

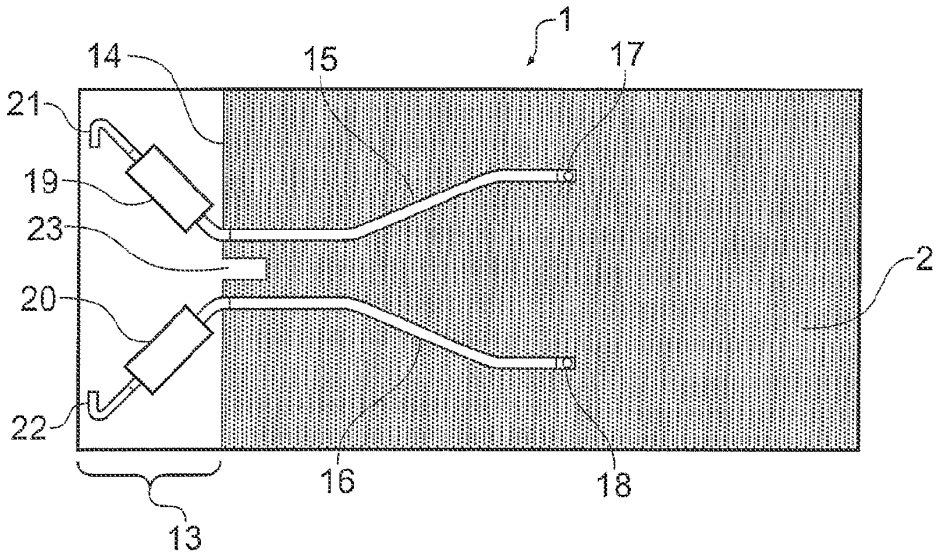


Fig. 3

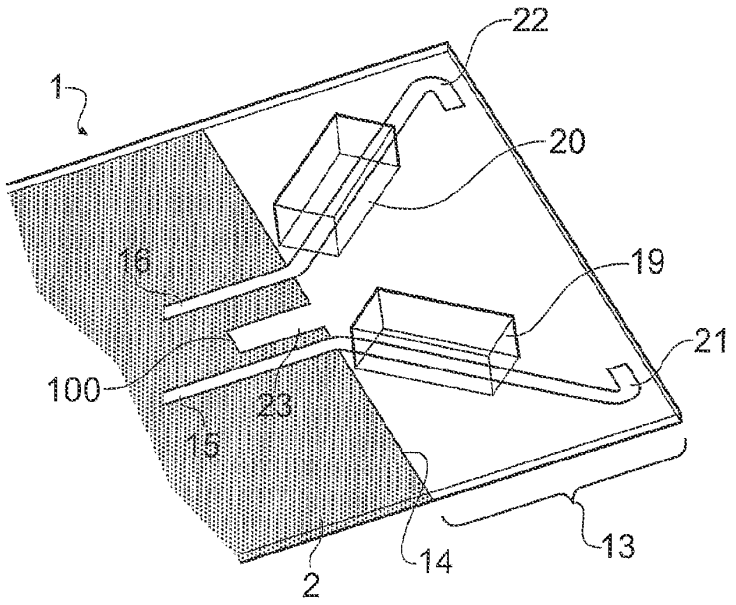


Fig. 4

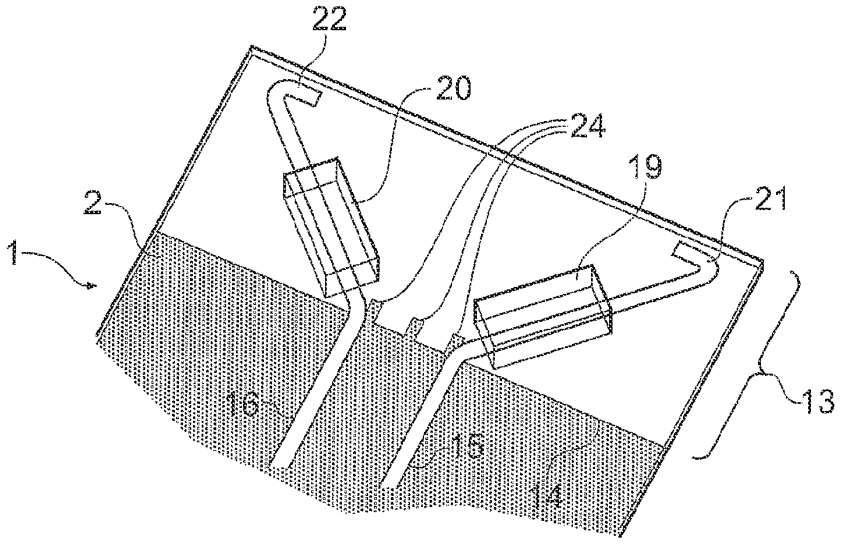


Fig. 5

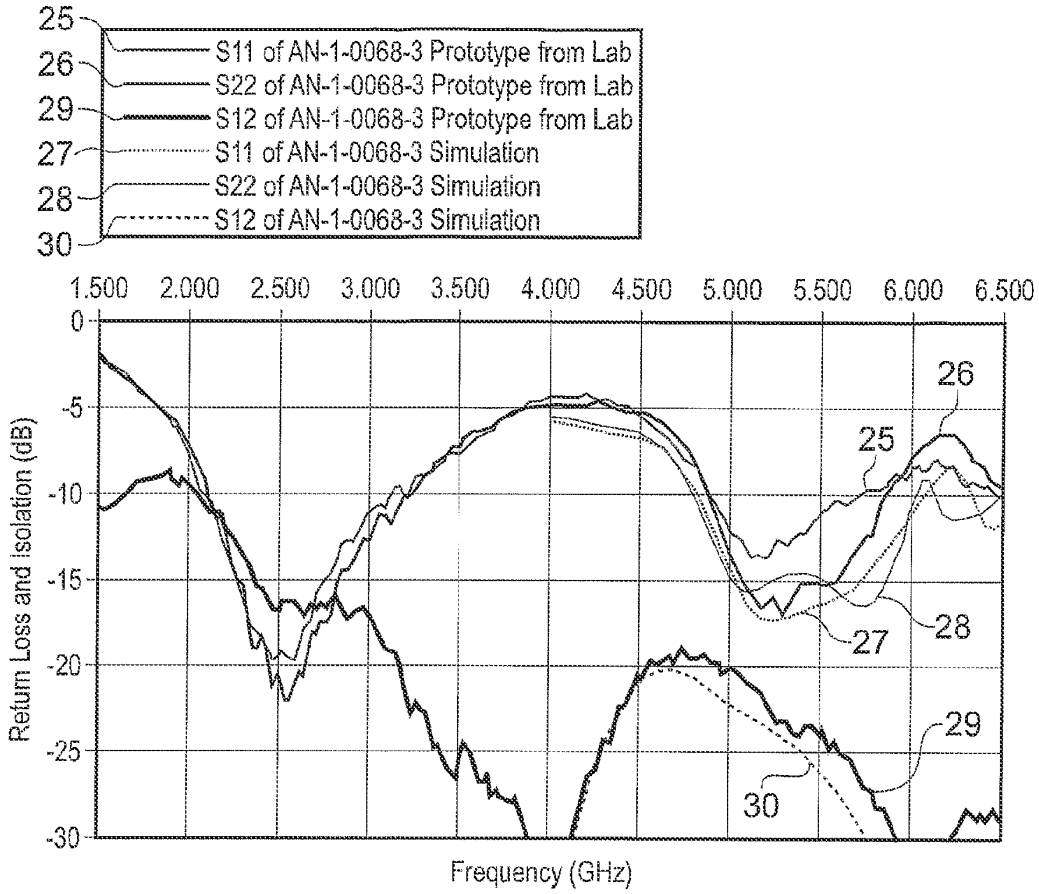

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29
27
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30
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S22 of AN-1-0068-3 Prototype from Lab
S12 of AN-1-0068-3 Prototype from Lab
S11 of AN-1-0068-3 Simulation
S22 of AN-1-0068-3 Simulation
S12 of AN-1-0068-3 Simulation
1.500 2.000 2.500 3.000 3.500 4.000 4.500 5.000 5.500 6.000 6.500
0
-5
-10
-15
-20
-25
-30
Return Loss and Isolation (dB)
Frequency (GHz)

Fig. 6

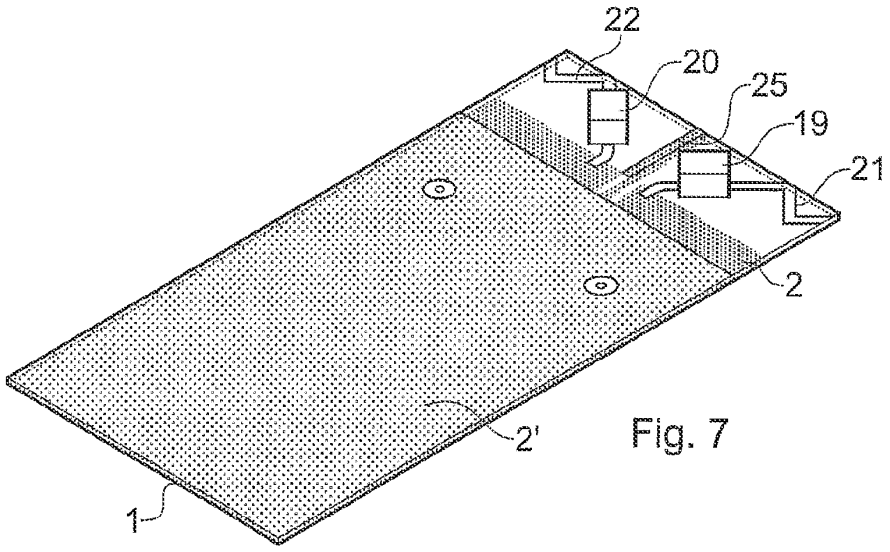

22
20
25
19
21
2
2'
1

Fig. 7

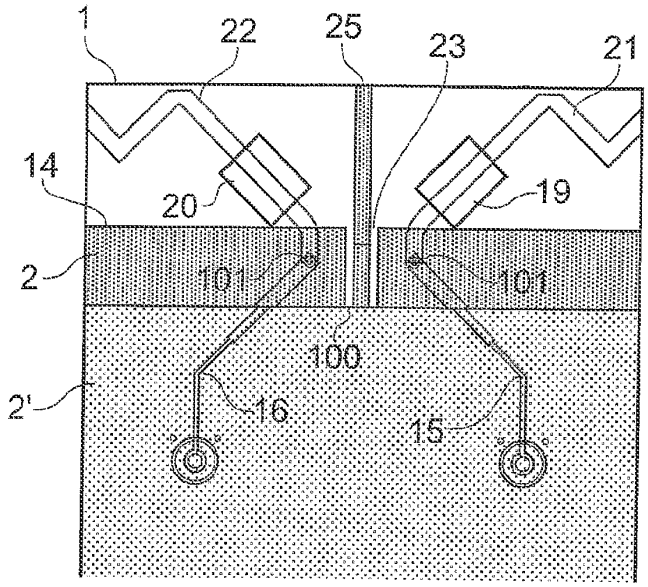


Fig. 8

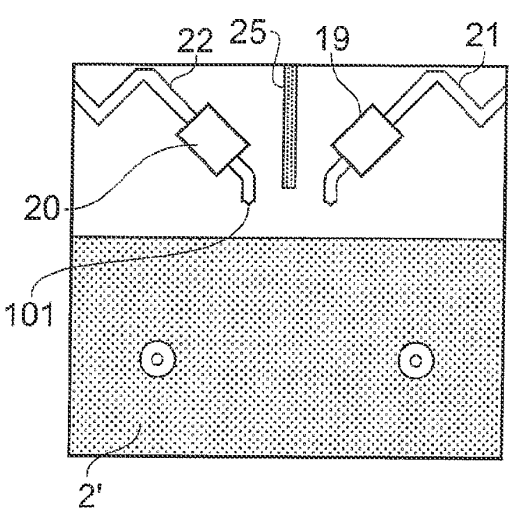


Fig. 9

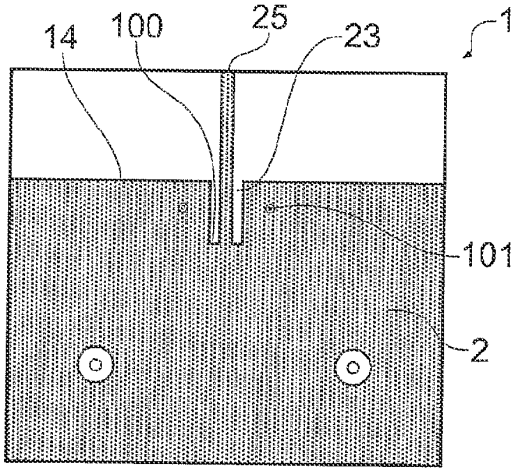


Fig. 10

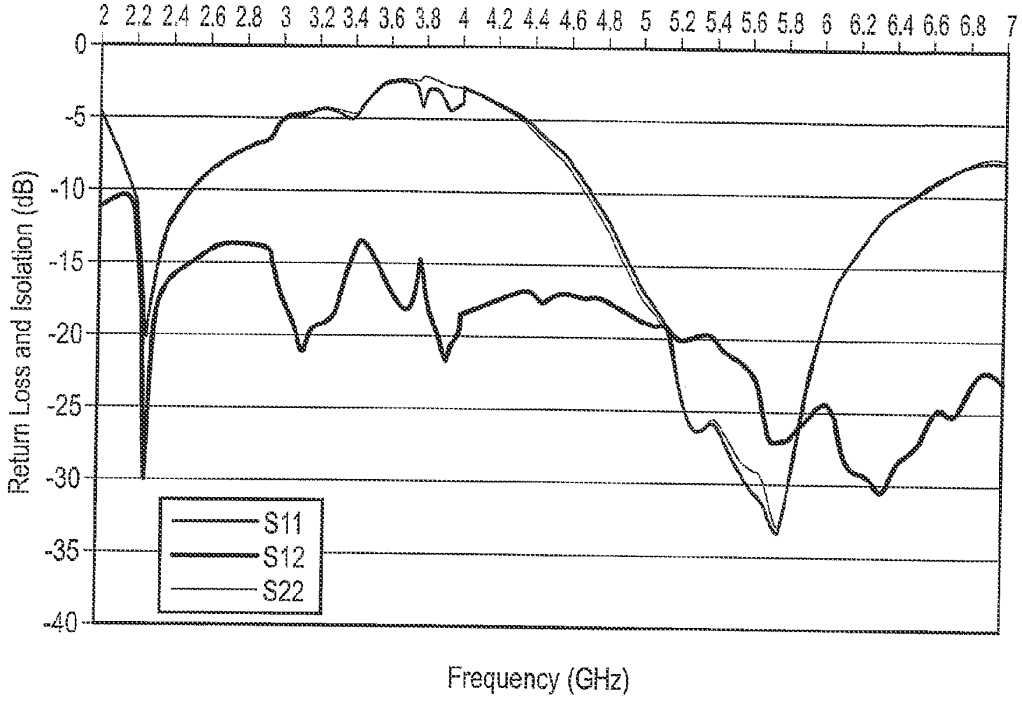

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0
-5
-10
-15
-20
-25
-30
-35
-40
Return Loss and Isolation (dB)
S11
S12
S22
Frequency (GHz)

Fig. 11

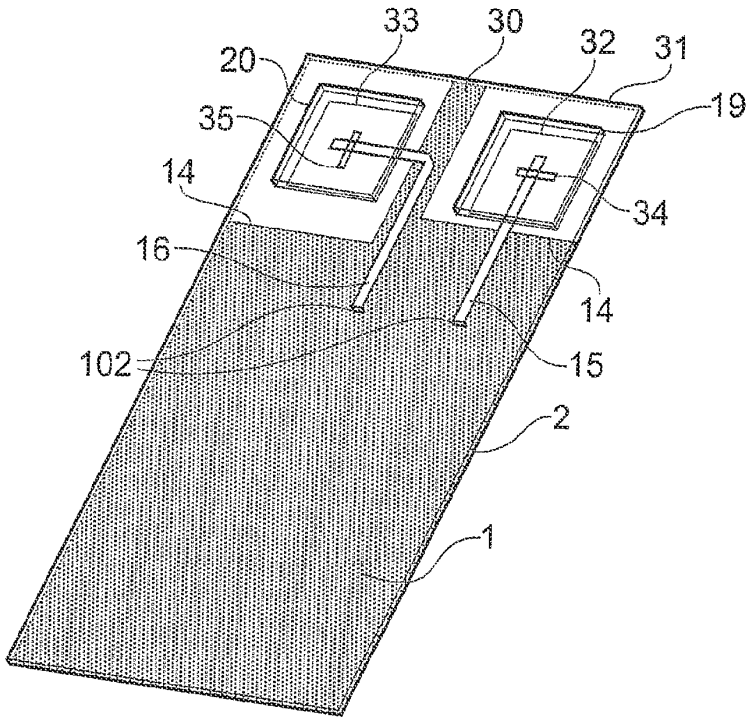


Fig. 12

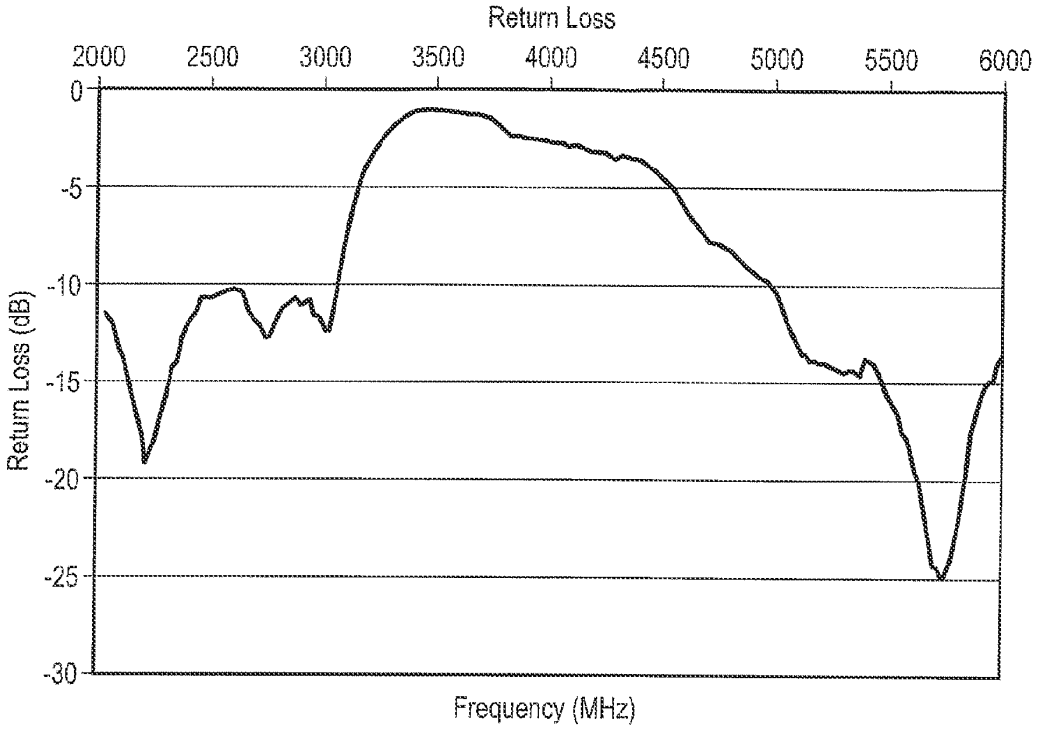

Return Loss
2000
2500
3000
3500
4000
4500
5000
5500
6000
0
-5
-10
-15
-20
-25
-30
Return Loss (dB)
Frequency (MHz)

Fig. 13

INTERNATIONAL SEARCH REPORT

national Application No
PCT/GB2004/002133

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q9/04 H01Q1/38 H01Q25/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WU TZUENN-YIH ET AL: "Printed diversity monopole antenna for WLAN operation" ELECTRONICS LETTERS, IEE STEVENAGE, GB, vol. 38, no. 25, 5 December 2002 (2002-12-05), pages 1625-1626, XP006019477 ISSN: 0013-5194 page 1625 - page 1626 figure 1	1-9, 16-18, 21-23
A		10-15, 19,20
Y	EP 0 828 310 A (MURATA MANUFACTURING CO) 11 March 1998 (1998-03-11) column 3, line 21 - line 45 column 4, line 29 - line 38 column 5, line 51 - column 6, line 11 figures 1,8	1-13, 16-21

-/--

[X] Further documents are listed in the continuation of box C. [X] Patent family members are listed in annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 August 2004	17/08/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Kruck, P

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2004/002133

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 549 170 B1 (KUO YEN LIANG ET AL) 15 April 2003 (2003-04-15) column 3, line 25 - line 38 figures 1,9	1,2,4, 6-9, 17-20
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Form PCT/ISA/210 (continuation of second sheet) (January 2004)

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International Application No
PCT/GB2004/002133

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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
2 December 2004 (02.12.2004)

PCT

(10) International Publication Number
WO 2004/105182 A1

(51) International Patent Classification[7]: H01Q 9/04, 1/38, 25/00

(21) International Application Number: PCT/GB2004/002133

(22) International Filing Date: 18 May 2004 (18.05.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0311361.0 19 May 2003 (19.05.2003) GB

(71) Applicant *(for all designated States except US)*: **ANTENOVA LIMITED** [GB/GB]; Far Field House, Albert Road, Stow-cum-Quy, Cambridge CB5 9AR (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **KINGSLEY, James, William** [GB/GB]; Far Field House, Albert Road,, Stow-cum-quy, Cambridge, CB5 9AR (GB). **MORGANS, Christopher** [GB/GB]; Far Field House, Albert Road,, Stow-cum-quy, Cambridge, CB5 9AR (GB). **BAGGALEY, Richard** [GB/GB]; Far Field House, Albert Road,, Stow-cum-quy, Cambridge, CB5 9AR (GB). **MARTIN, Steven** [GB/GB]; Far Field House, Albert Road, Stow-cum-Quy, Cambridge CB5 9AR (GB). **WYATT, Andrew** [GB/GB]; Far Field House, Albert Road,, Stow-cum-quy, Cambridge, CB5 9AR (GB). **KINGSLEY, Simon, Philip** [GB/GB]; Far Field House, Albert Road,, Stow-cum-quy, Cambridge, CB5 9AR (GB).

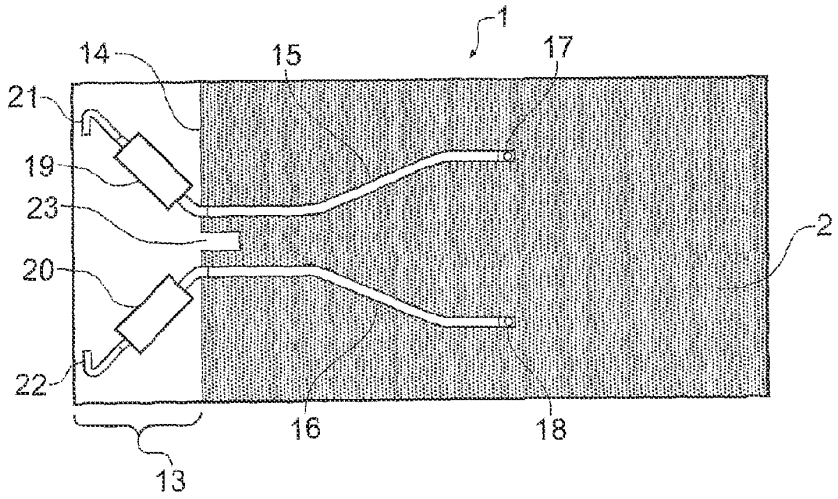
(74) Agent: **HARRISON GODDARD FOOTE**; Belgrave Hall, Belgrave Street, Leeds LS2 8DD (GB).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH,

[Continued on next page]

(54) Title: DUAL BAND ANTENNA SYSTEM WITH DIVERSITY



(57) Abstract: There is disclosed an antenna device comprising a dielectric substrate (1) with first and second opposed surfaces. A conductive ground plane (2) is formed on a first area of the second surface of the substrate (1), leaving a second area of the second surface blank. At least two conductive feedlines (15, 16) are formed on the first surface of the substrate (1) and, extend from an area corresponding to the first area of the second surface to an area corresponding to the second area of the second surface. Each feedline (15, 16) is provided with a dielectric element (19, 20) in the area corresponding to the second area of the second surface, and at least one slot or discontinuity (23, 24, 25) is formed in the conductive ground plane (2) at an interface (14) between the first and second areas in a region between the feedlines (15, 16). The antenna device displays good dual band operation with good diversity and isolation between the antenna elements.

WO 2004/105182 A1

GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:

— *of inventorship (Rule 4.17(iv)) for US only*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DUAL BAND ANTENNA SYSTEM WITH DIVERSITY

The present invention relates to a dual band antenna for use in mobile telephone handsets, PDAs (Personal Digital Assistants), PCMCIA cards, WLAN access points and other electrically small radio platforms. Embodiments of the present invention seek to provide a dual band antenna device having wide bandwidth in both bands and including two antenna elements so as to provide diversity.

Diversity is required to combat the multipath problem and is particularly needed when high data transmission rates are required.

Embodiments of the present invention may incorporate various types of antenna devices, including dielectric resonator antennas (DRAs), high dielectric antennas (HDAs), dielectrically loaded antennas (DLAs), dielectrically excited antennas (DEAs) and traditional conductive antennas made out of electrically conductive materials.

DRAs are well known in the prior art, and generally are formed as a pellet of a high permittivity dielectric material, such as a ceramic material, that is excited by a direct microstrip feed, by an aperture or slot feed or by a probe inserted into the dielectric material. A DRA generally requires a conductive groundplane or grounded substrate. In a DRA, the main radiator is the dielectric pellet, radiation being generated by displacement currents induced in the dielectric material.

HDAs are similar to DRAs, but instead of having a full ground plane located under the dielectric pellet, HDAs have a smaller ground plane or no ground plane at all. DRAs generally have a deep, well-defined resonant frequency, whereas HDAs tend to have a less well-defined response, but operate over a wider range of frequencies. Again, the primary radiator in the dielectric pellet.

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A DLA generally has the form of an electrically conductive element that is contacted by a dielectric element, for example a ceramic element of suitable shape. The primary radiator in a DLA is the electrically conductive element, but its radiating properties are modified by the dielectric element so as to allow a DLA to have smaller dimensions than a traditional conductive antenna with the same performance.

A further type of antenna recently developed by the present applicant is the dielectrically excited antenna (DEA). A DEA comprises a DRA, HDA or DLA used in conjunction with a conductive antenna, for example a planar inverted-L antenna (PILA) or planar inverted-F antenna (PIFA). In a DEA, the dielectric antenna component (i.e. the DRA, HDA or DLA) is driven, and a conductive antenna located in close proximity to the dielectric antenna is parasitically excited by the dielectric antenna, often radiating at a different frequency so as to provide dual or multi band operation. Alternatively, the conductive antenna may be driven so as parasitically to drive the dielectric antenna.

An important problem facing antenna designers, in particular today where many portable appliances such as computers, mobile telephones, computer peripherals and the like communicate with each other in a wireless manner, is to provide good diversity within a small space. In telecommunications and radar applications it is often desirable to have two or more antennas that give a different or diverse 'view' of an incoming signal. Generally speaking, the different views of the signal can be combined to achieve some optimum or at least improved performance such as maximum or at least improved signal to noise ratio, minimum or at least reduced interference, maximum or at least improved carrier to interference ratio, and so forth. Signal diversity using several antennas can be achieved by separating the antennas (spatial diversity), by pointing the antennas in different directions (pattern or directional diversity) or by using different polarisations (polarisation diversity). Antenna diversity is also important for overcoming the multi-path problem, where an incoming signal is reflected off buildings and other structures resulting in a plurality of differently phased components of the same signal.

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A significant problem arises when diversity is required from a small space or volume such that the antennas have to be closely spaced. An example of this is when a PCMCIA card, inserted into a laptop computer, is used to connect to the external world by radio. Most high data rate radio links require diversity to obtain the necessary level of performance, but the space available on a PCMCIA card is generally of the order of about 1/3 of a wavelength. At such a close spacing, most antennas will couple closely together and will therefore tend to behave like a single antenna. In addition, there is little isolation between the antennas and, consequently, there is little diversity or difference in performance between the antennas. As a rule, about –20dB coupling (isolation) is the target specification between antennas operating on the same band for a PCMCIA card. For access points (in WLAN and the like applications), which are rather like micro-base stations, even greater isolation is required, about -40dB being desirable. Such high isolation is extremely hard to achieve with conventional antennas when the access points are the size of domestic smoke alarms and less than a wavelength across. Similarly with laptop computers, isolation between WLAN and Bluetooth® antennas of –40dB or more is seen as desirable.

A method of creating good diversity at the Wireless Local Area Network (WLAN) frequency of 2.4 GHz has been published ["Printed diversity monopole antenna for WLAN operation", T-Y Wu, et. al., Electronics Letters, 38, 25, December 2002]. This paper describes how to remove the ground plane on the underside of a printed circuit board (PCB) so that the end section of a microstrip on the top surface becomes a radiating monopole. This is shown in Figure 1 of the present application. Wu et al. also describe how a T-shaped section of ground plane between the two antennas can help to increase port isolation between them. Further details are presented in ["Planar Antennas for WLAN Applications", K-L Wong, National Sun Yat-Sen University, Taiwan, presented at the 2002 Ansoft Workshop and available on the Ansoft website].

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The antenna system discussed above is relatively narrow band and no method of extending the bandwidth or other aspects of antenna performance, is offered. As described in the paper by Wu et al., this type of antenna does not have sufficient bandwidth to be used in a mobile communications system.

It is part of accepted antenna theory that 'fat' monopoles can be designed to have wider band performance than 'thin' monopoles, see for example, ["The handbook of antenna design", O. Rudge, et. al., Peter Peregrinus Ltd, 1986] where rectangular and conical shaped monopoles are shown to have very broadband responses. A recent paper ["Annular planar monopole antennas", Z. N. Chen, et. al., IEE Proc.-Microw. Antennas Propag., 149, 4, 200 – 203, 2002] describes how a monopole shaped as a circular disk or annulus can have broadband impedance and radiation characteristics. A recent book ["Broadband microstrip antennas", G. Kumar & K. P. Ray, Artech House, 2003] describes how the fat dipole concepts can be extended to printed microstrip antennas (MSAs). Figure 2 shows the general design of an MSA and Kumar & Ray show that rectangular, triangular, hexagonal and circular printed microstrip antennas all have broadband properties.

None of the references above make any mention of diversity or of using more than one monopole at a time, nor do they provide robust techniques for increasing isolation between antenna elements.

All of the references identified above are hereby incorporated into the present application by way of reference, and are thus to be considered as part of the present disclosure.

According to the present invention, there is provided an antenna device comprising a dielectric substrate with first and second opposed surfaces and having a width and a length, a conductive ground plane formed on a first area of the second surface of the substrate and leaving a second area of the second surface blank, at least two conductive feedlines formed on the first surface of the substrate or between the first

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and second surfaces and extending from an area corresponding to the first area of the second surface to an area corresponding to the second area of the second surface, each feedline being provided with a dielectric element in the area corresponding to the second area of the second surface, and at least one slot or discontinuity being formed in the conductive ground plane at an interface between the first and second areas in a region between the feedlines.

In some embodiments, a second dielectric substrate may be provided on the second surface so as to sandwich the groundplane between the dielectric substrate and the second dielectric substrate. It will be appreciated that this is entirely equivalent to a single dielectric substrate having the groundplane formed between the first and second surfaces. In these embodiments, the dielectric substrates are preferably the same size and shape, although this need not always be so.

In preferred embodiments, the interface extends generally across the width of the dielectric substrate, and may be formed as a substantially straight line except at the location of the slot or discontinuity. Where the dielectric substrate has a rectangular shape, the interface may extend generally parallel to an end edge of the dielectric substrate. Alternatively, the interface may be curved or may meander or may be formed at an angle or slope relative to an end edge of the dielectric substrate.

In a first preferred embodiment, the slot or discontinuity is formed as a gap or cut-out in the groundplane that extends generally towards a central part of the dielectric substrate from the interface. The gap or cut-out may have a length of around 5mm to 20mm or more, and may have a width of about 2mm to 10mm or more. The precise dimensions of the gap or cut-out will depend on the desired operating characteristics of the antenna device. The gap or cut-out may be generally rectangular, or may be trapezoidal or re-entrant in configuration, or may have any other desirable shape. What is important is that the gap or cut-out extends between the two feedlines on the side of the interface facing away from the location of the dielectric elements. A plurality of gaps or cut-outs, for example two, three, four or more, may be provided

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between the feedlines, for example by providing a castellated or crenellated edge to the interface between the feedlines. It will be appreciated that in these embodiments, the gaps or cut-outs extend generally into the groundplane from a basis line of the interface.

Alternatively, the discontinuity may be formed as one or more, preferably several, projections of the groundplane from the basis line of the interface into the second area, the projections being between the feedlines. The projections may be generally rectangular, or may be trapezoidal or any other suitable shape. Again, a castellated or crenellated profile may be formed in the groundplane at the interface and between the feedlines.

In a yet further embodiment, there may be provided at least one gap or cut-out in the groundplane extending generally away from the second area and between the feedlines, and a groundplane extension provided that extends from a base of the slot or cut-out, between (but not touching) sides of the slot or cut-out, towards an end edge of the dielectric substrate, the extension passing between the dielectric elements. The extension may optionally pass over the edge from the second surface of the dielectric substrate to the first, and then double-back along the first surface, generally following its line on the second surface, between the dielectric elements and the feedlines. The extension may terminate on the first surface at a point corresponding to the location of the gap or cut-out on the second surface, preferably behind the basis line of the interface and in the first area. In some embodiments, a second conductive groundplane may be provided on the first surface of the dielectric substrate (but electrically isolated from the feedlines). The second groundplane may terminate at an interface on the first surface that is somewhat set back from the interface on the second surface, for example at a position on the first surface corresponding to the base of the slot or cut-out on the second surface. The second groundplane can help to isolate the feedlines from external electromagnetic interference.

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Instead of projecting from a gap in the interface on the second surface, the groundplane extension may instead project directly from the interface.

A plurality of groundplane extensions may be provided, either extending from gaps in the interface or directly from the interface, or some combination of both.

Indeed, all embodiments of the present invention may include a second groundplane provided on the first surface for isolation purposes.

In a particularly preferred embodiment, the feedlines generally diverge from each other on the first surface of the dielectric substrate in the second area. For the best polarisation diversity, a divergence angle of substantially 90° is preferred, although a smaller or larger divergence angle may be used so as still to give beam diversity albeit with some sacrifice of polarisation diversity.

Dielectric elements are provided in association with the feedlines on the first surface in the second area. The dielectric elements may be made of dielectric ceramics materials with a dielectric constant (relative permittivity) greater than 5, and more preferably greater than 10 or greater than 100. The dielectric elements may various forms depending on the operational characteristics desired. For example, the elements may be formed as oblongs, wedges, trapezoids, parallelepipeds or other shapes, and may have edges or surfaces thereof ground or filed down so as to provide chamfers and curves.

One or more surfaces of each dielectric element, for example a top surface, a bottom surface and/or one or more side surfaces can be metallised or provided with a conductive coating. In particular, metallising a top surface of a dielectric element can help to reduce the size of the element required for a given operational frequency, or can help to adjust or change an operating frequency of the antenna thus formed.

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In currently preferred embodiments, two feedlines are provided, each feedline having one dielectric element associated therewith.

The feedlines may be formed as printed microstrip transmission lines or in any other appropriate manner.

The dielectric elements may be bonded to the feedlines in the second area on the first surface, for example by way of soldering or using an electrically conductive epoxy resin, or may be otherwise associated with the feedlines so as to form a dielectric antenna. Specific types of dielectric antenna configuration that are useful with the present invention include DRAs, HDAs, DLAs and DEAs as defined in the introduction to the present application. Full operational and structural details of these types of dielectric antennas are outside the scope of the present application, but further information may, for example, be found in the present applicant's co-pending application GB 2 388 964 the disclosure of which is hereby incorporated into the present application by reference.

In most embodiments, the dielectric elements will be mounted on top of the feedlines on the first surface.

The feedlines may extend beyond the dielectric elements, for example towards corners of the dielectric substrate in the second area, thus forming "tails" or "overhangs". The tails or overhangs may be substantially in line with the rest of the feedlines in the second area, or may include end portions that are bent or curved, for example towards or away from or generally parallel to a longitudinal centre line of the dielectric substrate. The tails or overhangs, and/or the feedlines generally, especially in the second area, may be curved or may meander or take various other configurations.

In some embodiments of the invention, PIN diode switches or other switches may be provided so as to switch in or out additional sections of feedline, for example at one

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or both of the tails or overhangs, thereby allowing an operating frequency of one or other of the dielectric antennas to be adjusted. This can be useful when the antenna device is to be used in different countries where one or other or both of an upper and a lower band needs to be raised or lowered to a different frequency.

In yet another embodiment, instead of providing the feedlines with tails or overhangs, a pair of isolated conductive plates or patches may be provided on the second surface of the substrate underneath the dielectric elements which are located on the first surface. The conductive plates or patches each have a slot which is arranged generally orthogonal to the respective feedline, which crosses over the slot. Advantageously, a groundplane extension is provided on the second surface so as to extend from the interface to an edge of the second area and passes between the conductive plates or patches.

In this embodiment, the dielectric elements may be formed as generally flat rectangular elements, which may be substantially square. The plates or patches may have a shape and area substantially the same as the dielectric elements, or may be slightly smaller or slightly larger. By making the elements flat, a low profile antenna device can be constructed, which is particularly advantageous in PCMCIA card applications. Preferably, the first and second feedlines are substantially orthogonal to each other where they pass under their respective dielectric elements, thus providing the best polarisation diversity.

One of the feedlines may follow (on the first surface) a path of the groundplane extension (on the second surface) before extending under its dielectric element.

In this embodiment, the slots radiate in one frequency band, and the plates or patches radiate in a second frequency band, thus providing dual band operation. The dielectric elements serve to provide a dielectric loading for both bands of operation and thereby help to make the antenna device more compact.

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For a better understanding of the present invention and to show how it may be carried into effect, reference shall now be made by way of example to the accompanying drawings, in which:

FIGURE 1 shows a prior art WLAN antenna device;

FIGURE 2 shows a prior art printed 'fat' monopole antenna device;

FIGURE 3 shows a first embodiment of the present invention;

FIGURE 4 shows an alternative first embodiment of the present invention;

FIGURE 5 shows a second embodiment of the present invention;

FIGURE 6 shows measured and simulated return losses of the antenna device of Figure 3 and the isolation between the antenna elements;

FIGURE 7 shows a perspective view of a third embodiment of the present invention;

FIGURE 8 shows a schematic plan view of the third embodiment;

FIGURE 9 shows a plan view of a part of the third embodiment;

FIGURE 10 shows an underplan view of a part of the third embodiment;

FIGURE 11 shows return loss and isolation for the third embodiment;

FIGURE 12 shows a schematic view of a fourth embodiment of the present invention; and

FIGURE 13 shows return loss for the antenna device of Figure 12.

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Figure 1 shows a prior art printed microstrip dual monopole antenna device, including a dielectric substrate 1 in the form of an FR4 PCB, a main conductive groundplane 2 on the underside of the substrate 1, two printed microstrip lines 3 on the upper side of the substrate 1, the lines 3 terminating in two radiating sections 4, and a small 'T'-shaped section of groundplane 5 on the underside of the substrate 1 in a location between the two radiating points 4.

Figure 1 also shows the device in cross-section, where it can be seen how the two microstrip lines 3 pass from the upper side of the substrate 1 to its lower side through a pair of gaps or holes 6 in the groundplane 2, and terminate in a pair of SMA connectors 7 which are electrically isolated from the groundplane 2 by insulating washers 8.

The two microstrip lines 3 are configured such that the radiating sections 4 point towards corners 9 of the substrate 1 and are disposed at 90 degrees to each other. No groundplane 2 is provided underneath the radiating sections 4.

This prior art antenna device has a narrow bandwidth in operation, and is acknowledged in the prior art to be unsuitable for mobile communications for this reason.

Figure 2 shows another prior art antenna device, also comprising a dielectric substrate 1 with a conductive groundplane 2 on its underside and a printed microstrip line 10 on its upper side. The line 10 terminates in a 'fat' section 11, which is significantly wider then the main section of the line 10, so as to define a radiating section 11. No groundplane 2 is provided under the radiating section 11. An edge 12 of the groundplane 2 acts as a groundplane for the radiating section 11. This antenna device has good bandwidth, but does not provide antenna diversity.

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Figures 3 and 4 show a first preferred embodiment of the present invention, comprising a dielectric substrate 1 in the form of an FR4 or Duroid® PCB. An underside of the substrate 1 is provided with a conductive groundplane 2 by metallization or any other suitable process, the groundplane 2 defining a first area of the substrate 1. An end portion 13 of the underside of the substrate 1 is not provided with a groundplane 2, this defining a second area of the substrate 1. An interface 14 is thus defined between the first and second areas of the substrate 1. In this embodiment, the interface 14 follows a generally straight line across the width of the substrate 1. First and second microstrip feedlines 15, 16 extend across the first area from feed points 17, 18 towards the second area, the feedlines 15, 16 being formed on the topside of the substrate 1. The feedlines 15, 16 run generally parallel to each other as they approach the second area, but as they cross the interface 14, the feedlines 15, 16 diverge at substantially 90 degrees to each other. Two dielectric elements 19, 20 in the form of oblong ceramics pellets are soldered or otherwise mounted on the divergent feedlines 15, 16 in the second area. The feedlines 15, 16 extend beyond the dielectric elements 19, 20 towards corners of the second area, thus defining tails or overhangs 21, 22. In the embodiment shown, the tails 21, 22 are bent towards each other, but in alternative embodiments the tails 21, 22 may be bent away from each other or may curve back towards the interface 14. This bending allows the antenna device as a whole to be made smaller, in particular the second area of the dielectric substrate. The tails 21, 22 act as dielectrically-loaded monopole antennas for operation in a lower frequency band (in this case, 2.1 to 3.1 GHz at a –10 dB return loss level), while the dielectric elements 19, 20 act as HDAs for operation in a higher frequency band (in this case, 4.9 to 6.1 GHz at a –10 dB return loss level).

A key feature of the invention in this embodiment is a gap or cut-out 23 formed in the groundplane 2 at the interface 14 and between the feedlines 15, 16. The gap 23 is generally rectangular in shape, and extends into the first area. The gap 23 serves to improve isolation between the two antennas formed by the respective tails 21, 22 and

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dielectric elements 19, 20. The gap 23 extends a predetermined distance from the interface 14 to a base 100 of the gap 23.

The antenna device of Figures 3 and 4 has been designed to cover the Bluetooth®/802.11g WLAN band at 2.4 GHz and all the high frequency 802.11a WLAN bands between 4.9 and 5.9 GHz. However, the technology is equally applicable to mobile phones or any other device requiring diversity and/or dual band functionality. Diversity is required to combat the multipath problem and is particularly needed when high data transmission rates are required.

Figure 5 shows an alternative embodiment, like parts being labelled as for Figures 3 and 4. The key difference is that, instead of a gap or cut-out being formed in the groundplane 2 at the interface 14 on the underside of the substrate 1, a set of three projections 24 is provided, the projections 24 having a castellated or crenellated configuration. The projections 24 extend into the second area from the first area on the underside of the substrate 1, and are located between the feedlines 15, 16 located on the topside of the substrate 1. The projections 24 serve to improve isolation between the two antennas formed by the respective tails 21, 22 and dielectric elements 19, 20.

It will be appreciated that multiple gaps or cut-outs 23 may be formed at the interface 14 of the embodiment of Figures 3 and 4, this resulting in a similar castellated or crenellated configuration to that of Figure 5, except that the base line of the interface 14 will define the tops of the castellations rather than the bottoms thereof.

The lengths of the tails 21, 22 may be increased so as to enable operation at lower frequencies in the lower band, for example to cover UMTS or GSM1800 bands. In some embodiments, additional lengths of feedline may be switched in or out of the tails 21, 22, for example by using PIN diode switches (not shown).

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Several prototype antenna pairs of the type shown in Figures 3 and 4 have been built and tested. Figure 6 shows the measured S_{11} return loss (line 25) for the left hand antenna of a prototype and the S_{22} return loss (line 26) for the right hand antenna. The measured –10 dB upper frequency limit for this prototype is about 5.9 GHz, but the simulated return losses (using Ansoft HFSS™) show that 6.1 GHz should be achieved - see the lines 27 and 28.

Also shown in Figure 6 are the measured S_{12} isolation between the antennas (line 29) and the upper band isolation from the simulation (line 30). There is very good isolation between the antennas in both the 2.4 GHz Bluetooth/802.11g band and the 5-6 GHz 802.11a bands.

The antennas have good gain and efficiency. In the lower band the gain is of the order of 2 dBi and in the upper band it is nearer 5 dBi. The efficiency is over 80%.

A further alternative embodiment is shown in Figures 7 to 10, with like parts being labelled as for the previous Figures. In addition to the groundplane 2 on the underside of the dielectric substrate 1, there is provided an additional groundplane 2' on the topside of the substrate. The additional groundplane 2' does not extend towards the end of the substrate 1 as far as the groundplane 2 on the underside, but terminates on the topside at a line corresponding to the location of the base 100 of the gap 23 formed in the groundplane 2 on the underside. A groundplane extension 25 is provided, which extends from the base 100 of the gap 23, but not touching the sides of the gap 23, to the edge of the underside of the substrate 1, and then returns back on itself on the topside of the substrate 1 to a point corresponding to a point just past the line of the interface 14. The feedlines 15, 16 on the topside are insulated from the additional groundplane 2', for example by being formed between the topside and the underside of the substrate 1, only moving up to the topside by way of vias 101 near the interface 14, and are provided with dielectric elements 19, 20 which are slightly shorter than those of the embodiments of Figures 4 and 5. As before, tails 21, 22 extend beyond the dielectric elements 19, 20 to act as dielectrically-loaded monopole

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antennas. The tails 21, 22 in this embodiment have a zig-zag configuration, which allows the tails 21, 22 to have a greater length in the space available than if the tails were straight.

This embodiment is particularly useful in PCMCIA applications, since the feedlines 15, 16 can be isolated from a PCMCIA chassis by way of being sandwiched between the groundplanes 2, 2'. The gap 23 and the extension 25 serve to provide improved isolation between the antenna elements 19, 21 and 20, 22 respectively.

The return loss and isolation between the antenna pair 19, 21 & 20, 22 can be seen in Figure 11. The antenna device as a whole has good coverage of both the WLAN 802.11b band at 2.4 GHz and the 802.11a band at 5-6 GHz.

Figure 12 shows a fourth embodiment of the present invention, comprising an antenna device including a dielectric substrate 1 having a first, upper surface and a second, lower surface, a conductive groundplane 2 on the second surface, and first and second conductive feedlines 15, 16 formed on the first surface and extending from feed points 102 in the first area on the first surface (located above the groundplane 2) to the second area of the first surface (located above regions with no groundplane). A groundplane extension 30 extends from the interface 14 on the second surface towards an edge 31 of the substrate 1. Two dielectric elements 19, 20, here in the form of low-profile squares of dielectric ceramics material, are provided on the first surface over the blank parts of the second surface (i.e. where there is no groundplane 2). The feedlines 15, 16 pass under the dielectric elements 19, 20 on the first surface, and are arranged orthogonal to each other at these points for maximum polarisation diversity. Two conductive plates or patches 32, 33 are provided on the second surface, located directly beneath the dielectric elements 19, 20 and having a similar size and shape. The conductive plates or patches 32, 33 each have a central slot or aperture 34, 35, the slots also being arranged orthogonal to each other. The feedlines 15, 16 are configured so as to cross over the slots 34, 35 generally orthogonal thereto, the feedlines 15, 16 and the dielectric elements 19, 20

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being on the first surface of the substrate 1 and the groundplane 2, groundplane extension 30 and the patches 32, 33 being on the second surface of the substrate 1. The slots 34, 35 radiate in one frequency band, and the patches 32, 33 radiate in a second frequency band, thus providing dual band operation. The dielectric elements 19, 20 serve as dielectric loads for both the slots 34, 35 and the patches 32, 33, thereby allowing the antenna as a whole to be more compact.

By making the dielectric elements 19, 20 relatively flat, a low profile antenna device can be constructed, which is particularly advantageous in PCMCIA card applications.

Figure 13 shows the return loss performance of the antenna device of Figure 12, demonstrating excellent dual band operation.

The preferred features of the invention are applicable to all aspects of the invention and may be used in any possible combination.

Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of the words, for example "comprising" and "comprises", mean "including but not limited to", and are not intended to (and do not) exclude other components, integers, moieties, additives or steps.

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CLAIMS:

1. An antenna device comprising a dielectric substrate with first and second opposed surfaces and having a width and a length, a conductive ground plane formed on a first area of the second surface of the substrate and leaving a second area of the second surface blank, at least two conductive feedlines formed on the first surface of the substrate or between the first and second surfaces and extending from an area corresponding to the first area of the second surface to an area corresponding to the second area of the second surface, each feedline being provided with a dielectric element in the area corresponding to the second area of the second surface, and at least one slot or discontinuity being formed in the conductive ground plane at an interface between the first and second areas in a region between the feedlines.

2. An antenna device as claimed in claim 1, wherein the interface extends across the width of the substrate on the second surface.

3. An antenna device as claimed in claim 2, wherein the interface is a substantially straight line except at a location of the slot or discontinuity.

4. An antenna device as claimed in claim 2, wherein the interface is curved or meanders across the width of the second surface.

5. An antenna device as claimed in any preceding claim, wherein the slot is formed as a gap or cut-out in the groundplane and extends by a predetermined distance from the interface into the first area.

6. An antenna device as claimed in any one of claims 1 to 4, wherein the discontinuity is formed as a projection of the groundplane and extends by a predetermined distance from the interface into the second area.

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7. An antenna device as claimed in claim 5 or 6, wherein a plurality of slots or discontinuities is provided at the interface, and wherein the plurality of slots or discontinuities has a castellated or crenellated configuration between the feedlines.

8. An antenna device as claimed in claim 5 or claim 7 depending from claim 5, wherein an additional groundplane extension line extends from a base of the gap or cut-out or at least one of the gaps or cut-outs on the second surface, over an edge of the substrate, and then across the first surface between the dielectric elements and the feedlines.

9. An antenna device as claimed in claim 6 or claim 7 depending from claim 6, wherein an additional groundplane extension line extends from the interface on the second surface, over an edge of the substrate, and then across the first surface between the dielectric elements and the feedlines.

10. An antenna device as claimed in any preceding claim, wherein the feedlines extend beyond the dielectric elements on the first surface so as to form tails or overhangs.

11. An antenna device as claimed in claim 10, wherein the tails or overhangs are bent or curved towards each other.

12. An antenna device as claimed in claim 10, wherein the tails or overhangs are bent or curved away from each other.

13. An antenna device as claimed in any one of claims 10 to 12, wherein the tails or overhangs have a zig-zag or meandering configuration.

14. An antenna device as claimed in claim 6, wherein the groundplane projection extends adjacent parts of the second area having no groundplane, and wherein the

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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 November 2004 (25.11.2004)

PCT

(10) International Publication Number
WO 2004/102744 A1

(51) International Patent Classification[7]: H01Q 21/30, 21/28, 13/10, 9/04, 1/24, 1/52

(21) International Application Number: PCT/IB2004/001533

(22) International Filing Date: 6 May 2004 (06.05.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0311077.2 14 May 2003 (14.05.2003) GB
0403765.1 20 February 2004 (20.02.2004) GB

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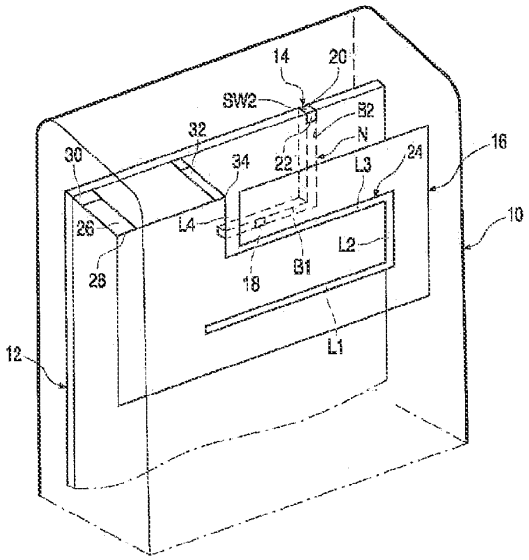
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(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: IMPROVEMENTS IN OR RELATING TO WIRELESS TERMINALS



(57) Abstract: A wireless terminal includes a housing (10) containing a substrate (12) having a ground plane, RF components mounted on the substrate, a PIFA (Planar Inverted-F Antenna)(16) carried by the substrate and coupled electrically to the RF components for transmitting and receiving signals and a notch antenna (14) in the substrate for receiving signals in a frequency band at least partially overlapping the transmission bandwidth of some of the signals transmitted by the PIFA. The notch antenna is de-activated when the PIFA (16) is being used for transmitting a signal lying within the said transmission bandwidth.

WO 2004/102744 A1

Declaration under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DESCRIPTION

IMPROVEMENTS IN OR RELATING TO WIRELESS TERMINALS

Technical Field

The present invention relates to improvements in or relating to wireless terminals. The invention has particular, but not exclusive, application to multiple standard cellular telephones operable in accordance telephone standards such as GSM (880 to 960 MHz), DCS (1710 to 1880 MHz) and PCS (1850 to 1990 MHz) and optionally Bluetooth ^{RTM} (ISM band in the region of 2.4GHz). The present invention also relates to a wireless module having an antenna and at least those components included in the coupling stages.

Background Art

In the course of developing successive generations of cellular telephones a great deal of effort has been spent on reducing the volume of the wireless terminal. Coupled with this reduction in the overall volume has been the desire to reduce the volume of the antenna whilst still maintaining its sensitivity. Externally mounted monopole antennas have been succeeded by internal antennas such as PIFAs (Planar Inverted–F Antennas) and notch antennas.

United States Patent Application Publication US 2003/0103010 A1 discloses a handset having a dual band antenna arrangement including a PIFA. PIFAs are popular with some manufacturers of handsets because they exhibit low SAR (Specific Absorption Rate) performance (and thereby less loss to the head) and they are installed above the phone circuitry and, therefore, "re-use" the space within the phone to some degree. The PIFA disclosed in this cited specification comprises a planar patch conductor mounted adjacent to, but spaced from, a ground conductor, usually a printed circuit board having at least the RF components mounted thereon. A first feed conductor is

connected to the patch conductor at a first point, a second feed conductor is connected to the patch conductor at a second point, and a ground conductor is connected to the patch conductor at a third point located between the first and second points. The impedance to which the antenna is matched can be changed by altering the relative thicknesses of the first, second and ground conductors. The PIFA is fed by a diplexer to which for example GSM and DCS circuitry is connected. In a variant the planar patch antenna has a slot which can be considered as dividing the planar conductor into two differently sized antennas connected to a common feed. The smaller of the two antennas is coupled to receive DCS frequencies and the larger of the two antennas is coupled to receive GSM frequencies. However, such antennas are physically large and are difficult to use over more than two cellular bands.

US Patent Specification No. 6,424,300 B1 discloses notch antennas for use in portable wireless terminals. The notch antenna is preferably formed in the ground plane conductor of a printed circuit board (PCB) that has RF circuitry thereon for receiving and transmitting RF signals. In this specification the notch antenna may be used as a primary antenna for radiating and receiving wireless communication signals or as a secondary antenna for receiving signals such as Bluetooth RTM or Global Positioning Signals (GPS). When the notch antenna is used as a secondary antenna, the primary antenna may comprise another notch antenna, an external monopole whip antenna or a PIFA. When the primary and secondary antennas are both notch antennas they preferably have orthogonal polarization directions which provides good isolation between them. Essentially this specification discloses a portable wireless terminal having two antennas, at least one of the two antennas being a notch antenna, for use in processing signals operating in accordance with a respective one of two standards. No arrangements are disclosed for use over more than two frequency bands

Disclosure of Invention

An object of the present invention is to reduce the antenna volume or increase the number of bands covered by a wireless terminal.

According to one aspect of the present invention there is provided a wireless terminal including a substrate having a ground plane, RF components mounted on the substrate and a PIFA (Planar Inverted-F Antenna) having connections electrically coupled to the ground plane, and the RF components characterised in that a notch antenna is provided in the substrate for receiving signals and in that de-activating means are provided for de-activating the notch antenna when the PIFA is being used for transmitting signals.

According to a second aspect of the present invention there is provided a wireless module comprising a substrate having RF components mounted thereon and means for connection to a PIFA (Planar Inverted-F Antenna), characterised in that a notch antenna is provided in the substrate and in that de-activating means are provided for de-activating the notch antenna.

The present invention is based on the realisation that the low SAR performance favours the use of a PIFA predominantly for transmission and a co-located notch can be used for reception (or in those applications when SAR is not considered to be important). A benefit of such an arrangement is that the antenna fractional bandwidth can be reduced if coverage of all the transmit and receive bands is divided between two or more antennas.

Brief Description of Drawings

The present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 are illustrations of how the cellular telephone bands are allocated in the USA and in Europe,

Figure 2 is a perspective diagrammatic view of a portable wireless terminal comprising co-located PIFA and notch antenna,

Figure 3 is a Smith chart relating to the PIFA S_{11},

Figure 4 is a Smith chart relating to the notch antenna S_{11},

Figure 5 is a combined schematic circuit diagram for operating the antenna arrangement shown in Figure 2,

Figure 6 illustrates the notch antenna being terminated by a passive network, and

Figure 7 is a block schematic diagram of the PIFA and the notch antenna being operated in a diversity mode.

In the drawings the same reference numerals have been used to indicate corresponding features.

Modes for Carrying Out the Invention

Figure 1 shows the European and North American cellular bands. The transmit bands Tx are shown in dark grey (to the left of each pair), while the receive bands Rx are shown in light grey (to the right). In Europe both the GSM and DCS bands, 880 to 960 MHz and 1710 to 1880 MHz, respectively, accommodate time division duplex systems, while the UMTS bands, 1920 to 1980 MHz (transmit) and 2110 to 2170 MHz (receive), are predominantly frequency division, full duplex. In the USA, a mix of systems and duplex methods are used in the AMPS and PCS bands, 824 to 894 MHz and 1850 to 1990 MHz, respectively. The advanced wireless systems (AWS) bands, 1710 to 1755 MHz and 2110 to 2155 MHz, have recently been allocated for 3G systems, though it has yet to be resolved how the bands will be used.

Currently many phones are being made to support the European GSM and DCS bands together with the US PCS bands (in the TDMA IS54/136 mode). Since many other countries have adopted either the European or US band allocations, this allows near-worldwide roaming. To cover these bands an antenna fractional bandwidth of 15.1% is required (1710–1990HMz). To cover the transmit bands only, a fractional bandwidth of only 11% is required, that is, the required bandwidth is reduced by approximately one third. To take advantage of this, the wireless terminal in accordance with the present invention uses a PIFA or PIFAs for the transmit bands and a notch or notches for the receive bands, for example the PCS Rx band. When the PIFA is used, the notch can be de-activated by switching across its open end. Since PIFAs and notches can occupy the same volume, and both antennas are required to

cover only a sub-section of the total bandwidth, the total volume occupied can be reduced compared to other known solutions.

Figure 2 is a perspective diagrammatic view of a portable wireless terminal comprising a housing 10 containing a substrate in the form of a printed circuit board (pcb) 12, typically measuring 40x100x1mm, carrying modules and other components constituting the RF, AF and control circuits of the wireless terminal. The pcb 12 also forms a ground plane of an antenna assembly consisting of a notch antenna 14 implemented in the pcb 12 and a dual-band GSM/DCS PIFA 16 mounted above the notch antenna 14 and lying in a plane parallel to, and spaced from, the pcb 12.

The notch antenna 14 comprises a L-shaped notch N in the pcb12. The notch N comprises a first, blind ended, branch B1 extending transversely of the pcb 14. An open end of the first branch B1 communicates with one end of a second branch B2, the other end of which branch B2 opens into the edge of the pcb 12. The notch N is fed at a selected point 18 near the blind end of the first branch B1 and a tuning/switching signal is applied to a selected point 20 adjacent to the open end of the second branch B2. The notch antenna 14 may be tuned by placing a tuning capacitor 22 at the selected point 20. With a small tuning capacitor, the notch antenna 14 can be used for Bluetooth^{RTM}, or any other frequency in the ISM band in the region of 2.4GHz (this varies from country to country), without adversely affecting the performance of the dual-band PIFA 16. With a larger tuning capacitor, the notch antenna 14 can be used for the PCS receive band (from 1930-1990MHz).

The PIFA 16 comprises a planar conductor having a meanderline slot 24 formed by a plurality of interconnected rectilinear sections L1, L2, L3 and L4. The section L1 is closed at one end and the section L4 opens into the upper edge of the planar conductor as viewed in Figure 2. The slot 24 can be considered as dividing the patch conductor into two antennas connected to a common feed, namely a smaller central radiator for the DCS/PCS frequency bands and a longer radiator, wrapped around the central radiator, for the GSM band. A feed connection 26 connects a corner 28 of the patch conductor to a connection point 30 at a corresponding corner of the pcb 12 and a ground

connection 32 connects the ground plane on the pcb 12 to a point 34 on the patch conductor located at the same side of the opening of the slot 24 as the corner 28.

In operation the notch antenna 14 may be tuned to the PCS receive band using the larger capacitor. As this frequency is close to the upper frequency at which the PIFA 16 operates, it is necessary to short circuit the notch at the open end when the PIFA is in use. This can be achieved via a simple switch SW2 (for example a PIN diode, FET or MEMs (Micro Electromagnetic Systems) device) placed at the selected point 20.

When the switch SW2 is on, that is conductive, the S_{11} performance of the dual-band PIFA 16 on a 40x100x1mm pcb 12 is as shown in the Smith chart illustrated in Figure 3. The Smith chart shows the simulated results for the frequencies f between 800 MHz and 3.0GHz, the source impedance being 50Ω. The markers s1 and s2 show the GSM band edges while markers s3 and s4 show the DCS band edges. It can be seen that the notch antenna 14 has no effect on the input impedance of the PIFA. The notch antenna 14 it is believed will not adversely affect the SAR.

In the simulation described above the total efficiency of the antenna (including mismatch) is greater than 60% over the GSM and DCS/PCS bands, despite the fact that the switch is assumed to have an on-resistance of just 10Ω. Hence it is demonstrated that, in the on-condition, the switch quality is not an important factor.

With the switch SW2 off, that is non-conductive, and an optimal tuning capacitance 22 for PCS receive is applied at the open end off the notch N, the S_{11} performance of the notch antenna 14 for the frequencies f between 800 MHZ and 3.0GHz is as shown in Figure 4. In Figure 4, the markers s1 and s2 show the PCS Rx band edges. In making this simulation the off-state is assumed to be provided by a PIN diode with a reverse bias capacitance of 0.2pF and a Q of 20. Under such conditions a worst-case efficiency (including mismatch) of 50% is achieved. It is believed that a better performance could be achieved with the use of better quality switches, such as MEMs devices.

Figure 5 schematically represents the above described circuit model for the PIFA 16 and the notch antenna 14.

In the GSM (transmit/receive mode) and the DCS transmit mode a switch SW1, which is operated in synchronism with the switch SW2, is connected to the PIFA feed point 26. A tuning capacitor 22 shunted by the switch SW2 is connected to the notch antenna 14. The operation of the switch SW2 is controlled by a controller 36. The feed point 18 is coupled by way of a capacitor C1 to an input of a PCS receiver 38. A further capacitor C2 couples the input to ground.

The feed connection 26 of the PIFA 16 is coupled by way of a series switch SW1 to a diplexer 40. The switch SW1 is controlled by the controller 36. A GSM/DCS/PCS transmitter 42 is coupled to an input of the diplexer 40 and an output of the diplexer is coupled to a GSM/DCS receiver 44.

In a transmit/receive mode the controller 36 operates the switches SW1 and SW2 in synchronism so that both are either on or off.

In the GSM/DCS/PCS transmit modes the switches SW1 and SW2 are in their on-condition. The transmitter 42 is coupled by way of the switch SW1 to the feed point 26 of the PIFA 16. The switch SW2 in its on-condition shunts the tuning capacitor 22 thereby detuning the notch antenna 14.

When the switches SW1 and SW2 are in their off-condition then no transmit signals are supplied to the feed point 26 and the tuning capacitor 22 is coupled to the notch antenna 14 to enable it to receive PCS signals. The received signals are conducted to the PCS receiver by way of the capacitor C1.

Figure 6 illustrates the use of a passive network 46 to prevent the notch antenna 14 transmitting signals. The passive network 46 has a bandstop filter characteristic which appears as an open circuit at the frequency of the notch antenna and a short circuit at the frequency of the PIFA. For example, the PIFA 16 may be used for UMTS Tx while the notch antenna 14 is used for UMTS Rx. Since both Tx and Rx are simultaneously required for UMTS, the notch antenna 14 can be made to look inactive at the UMTS transmit frequency by the tuning capacitor and the filter, that is, the passive network 46,

being effectively short circuited and active at the UMTS receive frequency by the tuning capacitor and the filter being effective as a result of the network 46 appearing as an open circuit. The passive network may be implemented as a bulk acoustic wave (BAW) resonator.

More than one notch antenna may be used, for example, for the simultaneous provision of GSM/DCS/PCS and Bluetooth^{RTM} or for the provision of diversity.

Figure 7 illustrates a simplified circuit arrangement for using the PIFA and notch antenna for switched diversity in which one or other of these antennas is selected based on signal quality/strength measurements and for simultaneous diversity in which the signals received by both antennas are combined. The outputs of both antennas are connected to inputs of respective amplifiers 48, 50. Outputs of these amplifiers are connected to a summing stage 52 which combines the outputs of the amplifiers.

Outputs of the amplifiers 48, 50 are also connected to a signal quality/strength measuring stage 54 which has an output coupled to the controller 36.

In the case of switched diversity the controller 36 controls the switches SW1, SW2 in the manner as described with reference to Figure 5, that is either both are in their on-condition or in their off-condition so that any one time only one or other of the PIFA or notch antenna is in use. In operation, with say the PIFA selected, a quality/strength measurement is made by the measuring stage 54. The controller 36 changes the conditions of the switches so that a measurement is made using the notch antenna 14.The results are compared and the better antenna is selected by the controller 36

In the simultaneous case, the controller controls the switches SW1, SW2 so that SW1 is in the on-condition and SW2 is in the off-condition, as shown. Signals from both the antennas are summed in the summing stage 52.

The present invention may be applied to any multi-band system where low SAR is only required for some of the bands. This is particularly appropriate for all current and future wireless communication systems.

Although the present invention has been described with reference to a wireless terminal having a PIFA antenna and operating in the GSM, DCS and PCS bands. The invention may be applied to any multiband radio and in other dual band applications.

In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Further, the word "comprising" does not exclude the presence of other elements or steps than those listed.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of wireless terminals and component parts therefor and which may be used instead of or in addition to features already described herein.

Industrial Applicability

Antennas, wireless modules and wireless terminals such as multiple standard cellular telephones.

Claims

1. A wireless terminal including a substrate having a ground plane (12) thereon, RF components mounted on the substrate and a PIFA (Planar Inverted-F Antenna)(16) having connections electrically coupled to the ground plane, and the RF components characterised in that a notch antenna (14) is provided in the substrate for receiving signals and in that de-activating means (SW1, SW2,36) are provided for de-activating the notch antenna when the PIFA (16) is being used for transmitting signals.

2. A wireless terminal as claimed in claim 1, characterised in that the PIFA is a dual band slotted planar patch antenna.

3. A wireless terminal as claimed in claim 1 or 2, characterised in that the de-activating means is responsive to activation of the notch antenna to de-activate the PIFA.

4. A wireless terminal as claimed in claim 1, 2 or 3, characterised in that the de-activating means comprises means for de-tuning the notch antenna.

5. A wireless terminal as claimed in claim 1,2 or 3, characterised in that capacitance means are connected across the notch for tuning the notch antenna and in that the means for de-activating the notch antenna comprises means for shorting the capacitance means.

6. A wireless terminal as claimed in claim 5, characterised in that the de-activating means comprises a passive network (46) presenting an open circuit at the operating frequency of the patch antenna and a short circuit at the operating frequency of the PIFA.

7. A wireless terminal as claimed in any one of claims 1 to 6, characterised in that the de-activating means has a diversity operating mode in which both the PIFA and the notch antenna are active in a receive mode and in that means are provided for summing output signals from the PIFA and the notch antenna.

8. A wireless terminal as claimed in any one of claims 1 to 5, characterised by means (54) for measuring the contemporaneous quality of signals received by the PIFA and the notch antenna and for selecting for receiving signals that one of the PIFA and notch antenna receiving the better quality signals.

9. A wireless module comprising a substrate (12) having RF components mounted thereon and means for connection to a PIFA (Planar Inverted-F Antenna)(16), characterised in that a notch antenna (14) is provided in the substrate and in that de-activating means (SW1, SW2) are provided for de-activating the notch antenna.

10. A wireless module as claimed in claim 9, characterised in that capacitance means are connected across the notch for tuning the notch antenna and in that the means for de-activating the notch antenna comprises means for shorting the capacitance means.

1/4

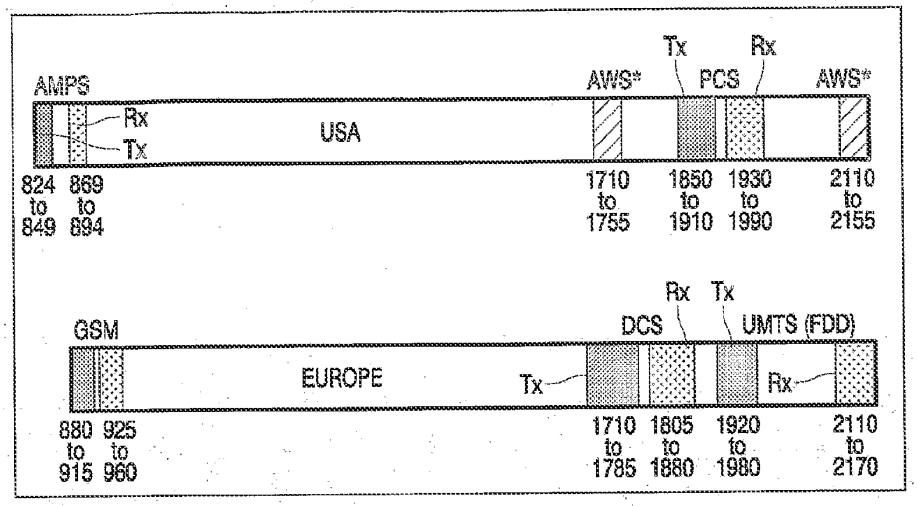

AMPS
Rx
Tx
USA
AWS*
Tx
Rx
PCS
AWS*
824 to 849
869 to 894
1710 to 1755
1850 to 1910
1930 to 1990
2110 to 2155
GSM
EUROPE
Tx
Rx Tx
DCS
UMTS (FDD)
Rx
880 to 915
925 to 960
1710 to 1785
1805 to 1880
1920 to 1980
2110 to 2170

FIG.1

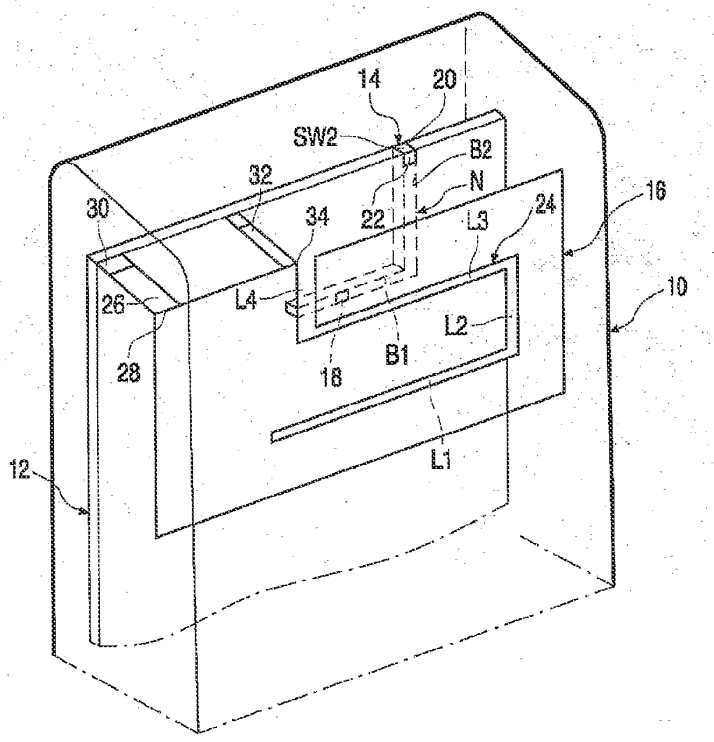
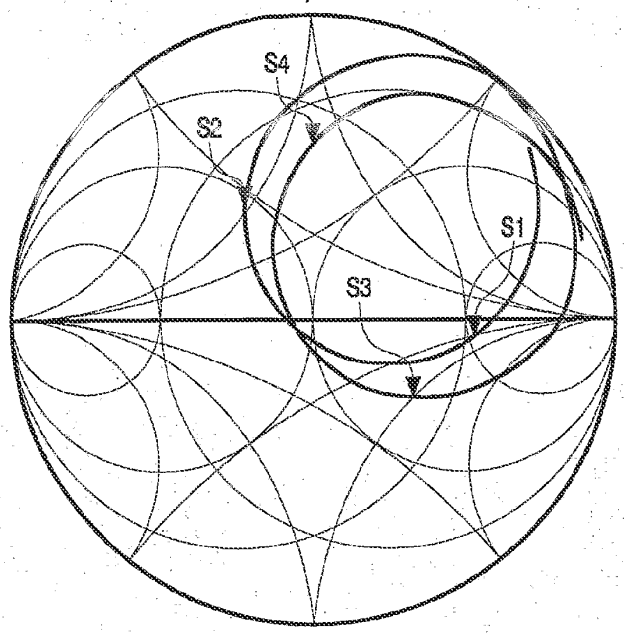
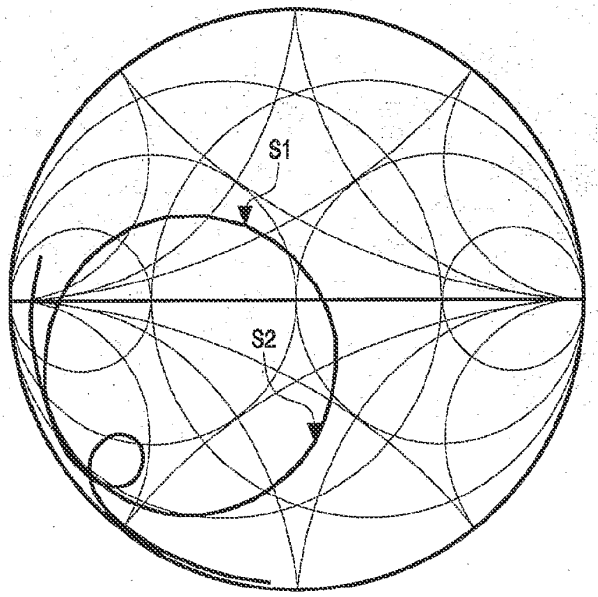

14
20
SW2
B2
N
32
30
34
22
L3
24
16
10
26
L4
L2
28
18
B1
L1
12

FIG.2



f (800.0Mhz to 3.000Ghz)

FIG.3



f (800.0Mhz to 3.000Ghz)

FIG.4

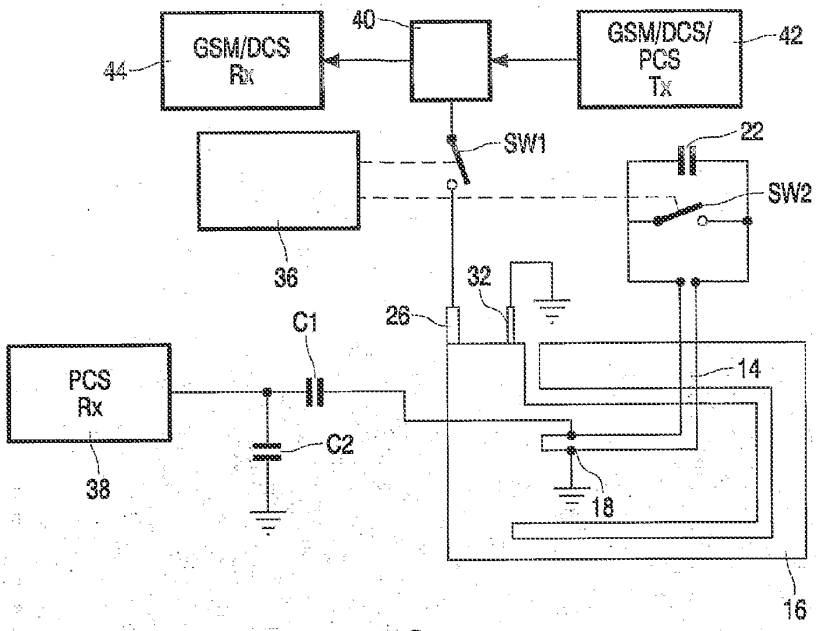

GSM/DCS
Rx
40
GSM/DCS/
PCS
Tx
42
44
SW1
22
SW2
36
32
26
C1
PCS
Rx
14
C2
38
18
16

FIG.5

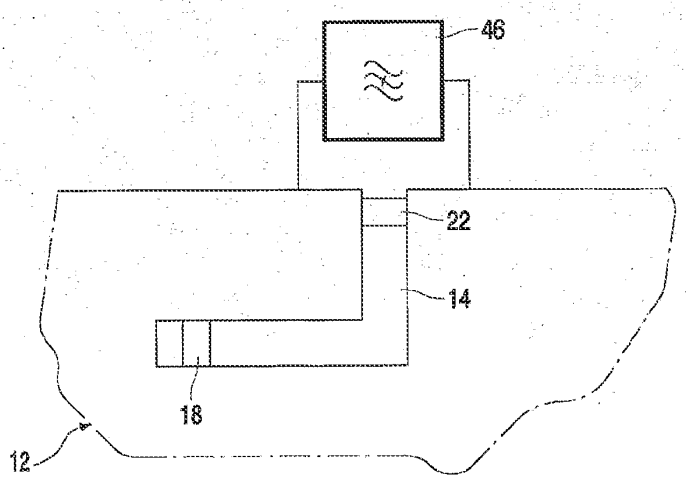

46
22
14
18
12

FIG.6

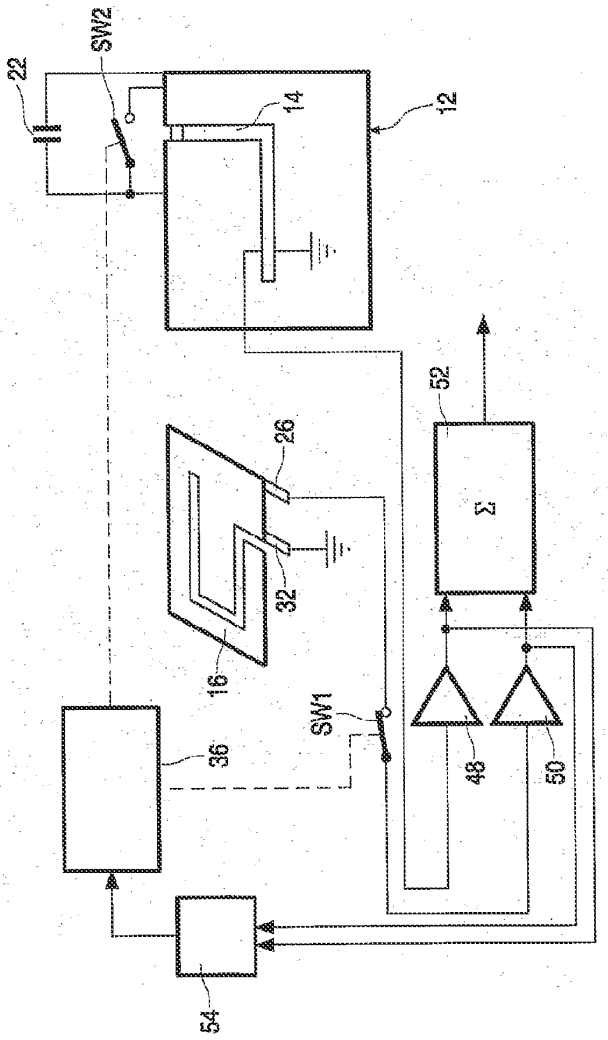


FIG.7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB2004/001533

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q21/30 H01Q21/28 H01Q13/10 H01Q9/04 H01Q1/24
H01Q1/52

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 August 2004	09/08/2004

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/IB2004/001533

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Form PCT/ISA/210 (continuation of second sheet) (January 2004)

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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
12 August 2004 (12.08.2004)

PCT

(10) International Publication Number
WO 2004/068631 A2

(51) International Patent Classification[7]: H01Q

(21) International Application Number:
PCT/US2004/002241

(22) International Filing Date: 26 January 2004 (26.01.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/248,543 28 January 2003 (28.01.2003) US

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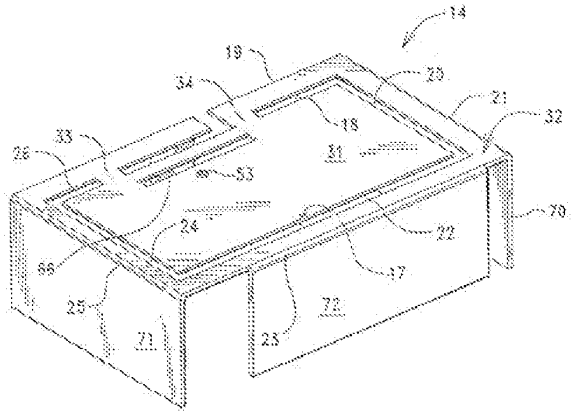
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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: A SINGLE-FEED, MULTI-BAND, VIRTUAL TWO-ANTENNA ASSEMBLY



(57) Abstract: A unitary assembly provides two virtual planar inverted F antennas (PIFAs) within a volume occupied by one of the PIFAs. The assembly includes a single RF feed, and provides multiple frequency response. A C-shaped slot divides a radiating element into an outer element and an inner element. Two metal stubs within a slot-discontinuity of the C-shaped slot physically and electrically connect the outer element to the inner element. An RF post connects to the outer element. The inner and outer elements are shorted to the ground plane. One metal stub provides virtual RF feed to the inner radiating element, the other metal stub provides a matching and/or tuning function to the radiating element, and the two metal stubs provide a matching and/or tuning function to the outer element. The outer element includes an L-shaped slot, and the inner element includes a linear slot. .

WO 2004/068631 A2

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A SINGLE-FEED, MULTI-BAND, VIRTUAL TWO-ANTENNA ASSEMBLY

RELATED PATENT APPLICATIONS

United States non-provisional patent application serial number 10/201,859, filed July 24, 2002, entitled DUAL FEED MULTI BAND PLANAR ANTENNA.

United States non-provisional patent application serial number 10/288,965, filed November 6, 2002, entitled PLANAR INVERTED-F ANTENNA (PIFA) HAVING A SLOTTED RADIATING ELEMENT PROVIDING GLOBAL CELLULAR AND GPS-BLUE TOOTH FREQUENCY RESPONSE.

FIELD OF THE INVENTION

This invention relates to the field of wireless communication, and more specifically to the construction of planar inverted-F antennas (PIFAs) for use in wireless communication devices such as mobile telephone handsets.

BACKGROUND OF THE INVENTION

The Advanced Mobile Phone Service (AMPS) and the Personal Communication Service (PCS) frequency bands, and the Global System for Mobile Communications (GSM) and the Digital Cellular System (DCS) frequency bands, form the basic dual cellular frequency bands within the US and within Europe, respectively.

There is a demand for wireless communication devices that will accommodate both the US AMPS/PCS frequency bands and the European GSM/DCS frequency bands within a single wireless communications device, so that a single wireless communications device, such as a cellular handset, can be used worldwide. This evolution toward a single cellular handset having global utility results in a need for cellular antennas that will simultaneously cover the AMPS/PCS/GSM/DCS frequency bands.

In addition, use of an antenna that is buried within, or is internal to, a cellular handset is desirable. Among the choices for an internal antenna for use within cellular handsets, a PIFA is very versatile in terms of its physical size and its performance.

In the past, multi-band PIFAs (for example two band or three band) have been provided having two or more RF feeds. However multi-feed PIFAs encounter disadvantages such as increased cost and increased mutual coupling that results from poor isolation.

Extension of a multi-feed multi-band PIFA in order to provide a global cellular PIFA (i.e. a PIFA that covers the AMPS/PCS/GSM/DCS frequency bands), cannot easily be accomplished due to the fact that the lower cellular frequency bands AMPS and GSM are close to each other, and in fact they have a region of frequency overlap, and the same is true

for the upper frequency cellular bands DCS and PCS. Due to this close frequency proximity of the relevant frequency bands, as well as the region of frequency overlap, the use of two PIFAs that operate separately in the AMPS/PCS frequency bands and the GSM/DCS frequency bands can be provided within a cellular handset. But this two-PIFA assembly requires that the two antennas occupy about twice the physical volume within a cellular handset that a single PIFA would require. In addition, partitioning the physical antenna-volume that is normally available within a practical and realistic cellular handset does not usually provide a desired separate resonance in both the AMPS frequency band and the GSM frequency band. Even if one were to succeed using such a two-PIFA design, providing adequate isolation between the two PIFAs is difficult. In view of these practical design constraints, the use of two PIFAs, having two feeds and having multiple frequency bands, is not a logical choice for the realization of a global cellular PIFA construction and arrangement.

Progress has been made in the cellular technology to provide a single-feed two-band PIFA. There also has been progress in the bandwidth enhancement of single feed two-band and three-band PIFAs.

Prior art PIFAs include a radiating/receiving element (hereinafter called a radiating element) having a length and a width that is optimized to approximate a quarter-wavelength within its semi perimeter. In order to reduce the resonant frequency of the PIFA without increasing its physical size, slots of different shapes have been used within the PIFA's radiating element. With the judicious choice of a slot configuration, and by optimizing the position of the radiating element's shorting post, PIFA designs have emerged for single-feed multi-band operation.

In prior art single-feed multi-band PIFAs, the multi-band operation is the result of a combination of the quasi physical partitioning of a single band PIFA's radiating element, wherein the radiating element is a derivative of a corresponding single-feed, single-band, PIFA.

In prior art dual-feed multi-band PIFAs having two radiating elements, the two radiating elements are physically isolated from each other.

In multi purpose cellular handsets that are usable in both cellular and non-cellular applications, a multi-band antenna that simultaneously operates in both the cellular and the GPS/Bluetooth frequency bands is of interest, wherein Bluetooth (BT) is a code name for a proposed open specification to standardize data synchronization between disparate PC and

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handheld PC devices. Single-band PIFAs have proven to be useful in meeting the demand of GPS/BT applications.

In prior art designs, an internal GPS band antenna has been used along with a dual-band cellular antenna, to thereby provide a dual-feed, three-band, two-antenna assembly. Such dual-feed three-band two-antenna assemblies have to encounter design complexities in order to ensure adequate isolation between the two feed ports that support the two cellular frequencies and the GPS frequencies.

Conventionally, a single-feed dual-band PIFA requires only one shorting post. In the prior art, slots of different shapes have been used in the radiating element of a PIFA, mainly to lower the resonant frequency of the radiating element without increasing the physical size of the PIFA. Although attempts have been made to provide a three-band PIFA by improving the bandwidth of a two-band PIFA, little or no success has been achieved relative to providing a single-feed four-band PIFA, or in providing for a simultaneous non-cellular band (GPS/ISM) resonance within the same four-band PIFA.

In certain PIFA designs, parasitic elements have been used in a dual-band PIFA to generate an additional resonance for non-cellular application.

In order to meet the demand of a global cellular antenna, United States Patent 6,255,994, provides for the multiple resonance of a PIFA by providing frequency-selecting switches for different resonant frequencies, so that the same telephone and antenna can be used globally. However, such a design results in an increased cost and additional complexities due to the increased number of electrical connections/components that are required for the antenna. In addition, and apart from the higher cost, the possibility exists for a gain degradation of the antenna when additional electrical components are introduced into the antenna.

SUMMARY OF THE INVENTION

This invention provides a single-feed four-band virtual two-PIFA assembly (hereinafter more conveniently called a two-PIFA assembly) that is responsive to the AMPS, PCS, GSM and DCS frequency bands, wherein this multi-band operation is realized by inserting the metal radiating element of one PIFA (i.e. an inner radiating element) within the metal radiating element of another PIFA (i.e. an outer radiating element).

A generally C-shaped slot separates the metal inner radiating element from the metal outer radiating element, and two spaced-apart metal stubs define the two ends of the C-shaped slot. That is, these two metal stubs are located in the discontinuity area of the C-

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shaped slot. These two metal stubs (the C-shaped slot's discontinuity area) physically and electrically connect the inner radiating element to the outer radiating element.

Separate metal shorting posts are provided for each of the inner and outer radiating elements, to thereby connect both of these radiating elements to a metal ground plane element that is located under, and generally parallel to, a plane that contains the two radiating elements.

The non-radiating edge of the outer radiating element is electrically connected to a single feed post, and one of the two metal stubs that connect the outer radiating element to the inner radiating element is located relatively close to this feed post, to thus provide a virtual feed to the inner radiating element.

RF energy is fed to and taken from the two-PIFA assembly by way of this single feed post, wherein at least one of the two metal stubs acts as a virtual RF feed for the inner radiating element.

The outer radiating element, having the single RF feed post and a shorting post located on its non-radiating edge, acts as a first PIFA. The inner radiating element, the metal stub(s) that acts as a virtual RF feed thereto, and a second shorting post that is electrically connected to the ground plane element, acts as a second PIFA.

While two metal stubs are provided in embodiments of this invention, more generally a plurality of metal stubs connect the inner radiating element to the outer radiating element. With reference to the above-mentioned first PIFA and its outer radiating element, this plurality of metal stubs provide a matching and/or tuning function. With reference to above-mentioned second PIFA and its inner radiating element, this plurality of metal stubs provides both a virtual RF feed, and a matching/tuning function.

In addition, the present invention provides a generally L-shaped slot that is punched or cut into a metal sheet that contains the above mentioned C-shaped slot, inner radiating element and outer radiating element. This generally L-shaped slot has an open end that is located on the non-radiating edge of the outer radiating element, at a location that is between this element's feed post and shorting post. This generally L-shaped slot provides a wide bandwidth and the desired dual resonant frequencies. This L-shaped slot on the outer radiating element results in the effective quasi physical partitioning of the outer radiating element, resulting in the dual resonant characteristics of that PIFA.

As above-described, two spaced-apart metal stubs connect the outer radiating element to the inner radiating element, and these two spaced-apart metal stubs terminate the two ends of the above-described C-shaped slot. That is, the placement-choice of these two metal stubs

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results in two separate slot-discontinuities in what would otherwise be a continuous slot that separates the inner and outer radiating elements.

The first metal stub slot-discontinuity that interrupts such a visualized continuous slot is preferably placed in close proximity to the feed post that is located on the non-radiating edge of the outer radiating element. The second metal stub slot-discontinuity in such a visualized continuous slot is placed in close proximity to the closed end of the L-shaped slot.

A virtual RF feed post for the inner radiating element is provided by way of the first slot-discontinuity (i.e. by the first metal stub) in the C-shaped slot, and the second slot-discontinuity (i.e. the second metal stub) in the C-shaped slot functions as a matching and/or tuning element for the inner radiating element. Thus, the first metal stub can be considered to be a virtual feed post for the inner radiating element, and the second metal stub can be considered to be a tuning/matching element for the inner radiating element.

In addition, and in view of the direct physical connection of the first and second metal stubs to the outer radiating element, the first and second metal stubs can be considered to be matching/tuning elements for the outer radiating element.

A single-feed multi-band two-PIFA assembly utilizing the "PIFA within a PIFA" construction and arrangement of the present invention also provides additional resonance in the GPS frequency band. Thus, the single-feed multi-band "PIFA within a PIFA" of the present invention finds utility in systems that simultaneously require cellular and non-cellular resonance.

This single-feed multi-band "PIFA within a PIFA" of this invention, having response in both cellular and non-cellular resonant frequency bands, is achieved by providing a composite radiating element having a generally C-shaped slot therein that divides the composite radiating element into an inner radiating element and an outer radiating element, to thus provide a single-feed multi-band two-PIFA-assembly construction and arrangement for global cellular communications, including the AMPS/GSM/DCS/PCS frequency bands.

The construction and arrangement of this invention provides a "PIFA within a PIFA" wherein the radiating element of one PIFA is inserted into the radiating element of another PIFA. The quasi physical separation that exists between these two radiating elements provides for very nearly independent control of the multiple resonant frequency bands of the two individual PIFAs that are within the two-PIFA assembly.

The combination of, and the physical location of, the generally L-shaped slot and the generally C-shaped slot, along with the two metal stubs that connect these two slots,

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facilitates tuning the resonant frequencies of the two-PIFA assembly to the desired frequency bands.

The physical position of a single feed post, the size and position of a first shorting post for the outer radiating element, the size and position of the metal stub that acts as a virtual feed for the inner radiating element, the size and position of a second shorting post for the inner radiating element, as well as the size and position of the metal stub(s) that act as a matching/tuning element for the inner radiating element, the position and dimensions of the L-shaped slot on the outer radiating element, and the position and the dimensions of the C-shaped slot on the inner radiating element, provide an impedance match for the multi-band performance of the two-PIFA assembly, wherein multi-band impedance matching is achieved without the need for an external matching network.

Single-feed multi-band two-PIFA assemblies in accordance with the present invention provide resonant frequencies having utility in both cellular and non-cellular applications, wherein a single, unitary, two-PIFA assembly provides a "PIFA-within-a PIFA" construction and arrangement, and wherein it is relative ease to control the resonant characteristics of the two-antenna assembly so that the assembly in accordance with this invention exhibits resonance performance that is adequate for global cellular communication, including the AMPS/GSM/DCS/PCS frequency bands, without requiring a switch or an external matching network.

From the structural point of view, multi-band two-PIFA assemblies in accordance with the invention require only that an additional shorting post be provided for the inner radiating element, and the composite radiating element of the multi band two-PIFA assembly is amenable for large-scale manufacturing by punching/cutting, and then bending, a single piece of metal.

In accordance with a feature of this invention, a single metal sheet or plate is punched or cut in order to provided (1) a generally C-shaped slot that separates the metal sheet into an inner radiating element and an outer radiating element, (2) an L-shaped slot and a linear slot that are associated with the two radiating elements, (3) at least two metal stubs that interrupt the generally C-shaped slot and structurally support the inner radiating element in a cantilever fashion, (4) a metal shorting post for connecting the outer radiating element to a ground plane, (5) a metal feed post for transmitting RF energy to and from the outer radiating element, and (5) a plurality (for example three) metal plates that are connected to the edges of the outer radiating element.

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Single-feed multi-band two-PIFA assemblies in accordance with the invention resonate in the AMPS/PCS frequency bands and the GSM/DCS frequency bands, as well as in the GPS frequency band, and they provide great potential for utility in global cellular handsets and in system applications that require simultaneous cellular and non-cellular operation.

Many original equipment manufacturers (OEMs) desire a cellular antenna, and more specifically an internal cellular antenna, that operates in both the US cellular (AMPS/PCS) and the European cellular (GSM/DCS) bands. The single-feed multi-band two-PIFA assembly of this invention, having four band (AMPS/GSM/DCS/PCS) performance, is an appropriate choice for these OEMs. In view of an additional resonance in the non-cellular (GPS) frequency band, the multi-band two-PIFA assemblies of this invention have additional utility in systems requiring simultaneous cellular and non-cellular operations.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded top and side perspective view of a two-PIFA assembly in accordance with the invention, this figure showing a metal sheet that contains a generally C-shaped slot that divides the metal sheet into an inner radiating element and an outer radiation element, this figure showing a four sidewall and box-like dielectric carriage whose sidewalls support the composite, inner/outer, radiating element above a metal ground plane element, this figure showing a metal feed post that extends downward from the non-radiating edge of the outer radiating element and along a sidewall of the dielectric carriage so that a free end of this metal feed post is physically spaced above the ground plane element, this figure showing a first metal shorting post that extends downward from the non-radiating edge of the outer radiating element and along the same sidewall of the dielectric carriage so that an end of this first metal shorting post is electrically connected to the ground plane element, and this figure showing a second metal shorting post that extends downward closely adjacent to the non-radiating edge of the inner radiating element so that an end of this second shorting post is electrically connected to the ground plane element.

FIG. 2 is a perspective view of the composite radiating element of FIG. 1, this figure better showing the radiating edge of the outer radiating element and the radiating edge of the inner radiating element.

FIG. 3a is a top view the composite radiating element and three-slot arrangement of FIGS. 1 and 2, wherein a composite slot includes (1) a C-shaped slot, (2) an L-shaped slot having a slot-segment that appears to be a continuation of the C-shaped slot, and (3) a linear slot that is positionally displaced from, and parallel to, the above-mentioned slot segment of

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the C-shaped slot, this figure also showing the two metal stubs that extend between the inner and outer radiating elements.

FIG. 3b shows only the L-shaped slot of FIG. 3a, with the open end of the L-shaped slot being located on the non-radiating edge of the outer radiating element.

FIG. 3c shows a combination of the C-shaped slot, the linear slot of FIG. 3a, and the two spaced-apart metal stubs that extend between the inner and outer radiating elements.

DETAILED DESCRIPTION

FIG. 1 is an exploded top and side perspective view of a two-PIFA assembly 10 in accordance with the invention, i.e. a "PIFA-within-a PIFA" assembly 10 in accordance with the invention.

Two-PIFA assembly 10 includes a generally flat metal sheet 11 that functions as a common ground plane element of the two-PIFA assembly. Ground plane element 11 includes a major or long axis 12 and a minor or short axis 13 that extends perpendicular to major axis 12.

By way of a non-limiting example, in an embodiment of the invention the major length 12 of ground plane element 11 was about 4.33 inch, the minor width 13 of ground plane element 11 was about 1.65 inch, and the height of the assembled two-PIFA assembly 10 (i.e. the dimension measured perpendicular to the plane of ground plane element 11) was about 0.394 inch.

Reference number 14 designates a composite metal radiating element that contains a C-shaped slot that divides composite radiating element 14 into an inner radiating element 31 and an outer radiation element 32 that generally surrounds inner radiating element 31. By way of example only, in an embodiment of the invention dimension 42 of composite radiating element 14 was about 1.54 inch and dimension 43 was about 0.95 inch.

Referring to FIG. 3a for example, composite radiating element 14 is made of a metal sheet that is punched or cut so as to form (1) a generally C-shaped open slot 17, (2) a generally L-shaped open slot 60, and (3) a generally linear open slot 66 therein.

This processing of the metal sheet provides a metal sheet that includes (1) metal inner radiating element 31, (2) metal outer radiating element 32 that generally surrounds inner radiating element 31 and that occupies generally the same plane as inner radiating element 31, and two metal stubs 33 and 34 that extend between inner radiating element 31 and outer radiating element 32 and that occupy generally the same plane as the two radiating elements.

Generally C-shaped slot 17 includes (1) a first slot segment 18 that extends generally parallel to the non-radiating edge 19 of composite radiating element 14 and generally parallel

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to the minor axis 13 of ground plane element 11, (2) a second slot segment 20 that extends generally parallel to the side edge 21 of composite radiating element 14 and generally parallel to the major axis 12 of ground plane element 11, (3) a third slot segment 22 that extends generally parallel to the minor axis 13 of ground plane element 11 and generally parallel to the radiating edge 23 of composite radiating element 14, (4) a fourth slot segment 24 that extends generally parallel to the major axis 12 of ground plane element 11 and generally parallel to the side edge 25 of composite radiating element 14, and (5) a fifth slot segment 26 that extends generally parallel to the minor axis 13 of ground plane element 11 and generally parallel to the non-radiating edge 19 of composite radiating element 14.

C-shaped slot 17 is interrupted by two metal stubs 33 and 34. Metal stubs 33 and 34 physically support inner radiating element 31. As will be apparent, at least metal stub 34 acts as a virtual RF feed for inner radiating element 31, at least metal stub 33 acts as a matching/tuning element for inner radiation element 31, and the two metal stubs 33 and 34 act as matching/tuning elements for outer radiating element 32.

Reference number 37 in FIG. 1 designates a box-like and rigid dielectric carriage having four sidewalls 38, 39, 40 and 41 that support composite, inner/outer, metal radiating element 14 above metal ground plane element 11. By way of a non-limiting example, dielectric carriage 37 may be made of High Density Poly Ethylene (HDPE), PolyCarbonate, or Acrolonitrite Butadiene Styrene (ABS).

In a non-limiting embodiment of the invention, the four sidewalls 38, 39, 40 and 41 of dielectric carriage 37 were of generally equal height (the dimension measured generally perpendicular to ground plane element 11) and were about 0.079 inch thick, they defined a generally rectangular cross-section open cavity 75 between composite radiating element 14 and ground plane element 11, the two opposite sidewalls 38 and 40 were of generally equal length and were parallel, the two opposite sidewalls 39 and 41 were of generally equal length and were parallel, and sidewalls 39 and 41 extended perpendicular to sidewalls 38 and 40.

Composite radiating element 14 (composed of inner radiating element 31 and outer radiating element 32) includes a single metal feed post 45 that is bent to extend generally 90-degrees downward from the top planar surface of composite radiating element 14. That is, metal feed post 45 extends downward from the non-radiating edge 19 of composite radiating element 14. In practice, metal feed post 45 lies closely adjacent to, or abuts against, the sidewall 38 of dielectric carriage 37.

When the two-PUFA assembly 10 of FIG. 1 is assembled, the end 46 of feed post 45 is spaced from the top and generally planar surface of ground plane element 11, at a location

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that is relatively close to the edge 47 of ground plane element 11. A coaxial feed cable, generally identified at 48, is connected to the end 46 of feed post 45 so as to provide a means whereby RF energy is received from and supplied to composite radiating element 14.

A first PIFA that includes outer radiating element 32 is provided with a first metal shorting post 50 that is bent so as to extend generally 90-degrees downward from the top planar surface of composite radiating element 14. That is, this first metal shorting post 50 extends downward from the non-radiating edge 19 of composite radiating element 14. In practice, metal shorting post 50 lies closely adjacent to, or abuts against, the sidewall 38 of dielectric carriage 37.

When the two-PIFA assembly 10 of FIG. 1 is assembled, the end 51 of this first shorting post 50 physically engages, and is electrically connected to, the top and generally planar surface of ground plane element 11 at a location that is relatively close to the edge 47 of ground plane element 11.

In the construction and arrangement of this first PIFA, metal feed post 45 provides a means for supplying RF energy to outer radiating element 32, and for receiving RF energy from outer radiating element 32, as outer radiating element 32 cooperates with ground plane element 11, and as the non-radiating edge 19 of outer radiating element 32 is shorted to ground plane element 11 by the first shorting post 50.

The second PIFA of FIG. 1's two-PIFA assembly 10 includes inner radiating element 31. A second metal shorting post 52 extends generally 90-degress downward from the plane of inner radiating element 31, at a location that is closely adjacent to the non-radiating edge of inner radiating element 31, as this non-radiating edge is generally defined by the inner edges of the two slot segments 18 and 26.

When the two-PIFA assembly 10 of FIG. 1 is assembled, the top end of this second metal shorting post 52 is electrically connected to inner radiating element 31 at a location that is designated by number 53, and the bottom end of this second metal shorting post 52 is electrically connected to ground plane element 11 at a location that is spaced from, but is closely adjacent to, the edge 47 of ground plane element 11.

With reference to FIG. 1, the metal stub 34 that is located close to feed post 45 provides a virtual RF feed electrical connection to inner radiating element 31 whereby RF energy is supplied to inner radiating element 31 and RF energy is received from inner radiating element 31, as inner radiating element 31 cooperates with ground plane element 11, and as the non-radiating edge portion of inner radiating element 31 is shorted to ground plane element 11 by the second shorting post 52.

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In the construction and arrangement of this second PIFA, virtual feed 34 provides a means for supplying RF energy to inner radiating element 31, and for receiving RF energy from inner radiating element 31, as inner radiating element 31 cooperates with ground plane element 11, and as the non-radiating portion of inner radiating element 31 is shorted to ground plane element 11 by the second shorting post 52.

Composite radiating element 14 also includes an L-shaped slot 60 having an open end 61 that is located on the non-radiating edge 19 of composite radiating element 14, at a location that is between feed post 45 and the first shorting post 50.

L-shaped slot 60 is made up two slot segments, i.e. a first slot segment 62 that extends generally perpendicular to non-radiating edge 19 and generally parallel to the major axis 12 of ground plane element 11, and a second slot segment 63 that extends generally parallel to non-radiating edge 19 and generally parallel to the minor axis 13 of ground plane element 11.

L-shaped slot 60 forms a quasi physical partitioning of a single band PIFA structure, wherein the term single band PIFA structure implies that composite radiating element 14 is devoid of any slot, and that its resonant frequency is primarily dependent upon the semi perimeter of composite radiating element 14 as well as on the separation distance between composite radiating element 14 and ground plane 11.

The quasi physical partitioning that is realized by providing L-shaped slot 60 within composite radiating element 14 transforms such a single band PIFA structure into the multi-band PIFA whose resonant frequencies are dependent not only on the linear dimensions of the PIFA, but also on the size of L-shaped slot 60, with the resonant frequencies also being influenced by the physical locations of first shorting post 50 and feed post 45.

In general, the slots within composite radiating element 14 (straight/linear or L-shaped) serve the dual purpose of imparting quasi physical partitioning, as well as imparting reactive loading to the PIFA structure. Reactive loading lowers the resonant frequency of such a PIFA, without increasing its physical size. Slot length is a significant parameter that determines the realizable reactive loading.

In the single-feed multi-band PIFA 10 wherein both feed post 45 and the first shorting post 50 are aligned along a line that is parallel to the minor axis 13 of ground plane 11, it is generally observed that a straight slot having its axis parallel to the major axis 12 of ground plane 11, and having its open end on non-radiating edge 19, may not realize a desired resonance in the cellular bands (AMPS/GSM) when there is a constraint on the allowable length (i.e. the linear dimension parallel to the major axis 12 of ground plane 11). This

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constraint on the length of PIFA 10 would limit the maximum permissible length of a straight/linear slot.

To overcome this limitation, L-shaped slot 60 is preferred, L-shaped slot 60 having a vertical segment 62 that is parallel to the major axis 12 of ground plane 11, and having a horizontal segment 63 that is parallel to the minor axis 13 of ground plane 11.

The combined length of L-shaped slot 60 enhances the realizable reactive loading even when there is a constraint on the linear dimension of PIFA 10. When the open end 61 of L-shaped slot 60 is located between feed post 45 and the first shorting post 50 of PIFA 10, an additional advantage is provided in that the bandwidth centered around both the lower and upper resonant frequencies is increased.

Composite radiating element 14 also includes a generally linear slot 66 that is closely spaced inward from slot segment 63, so as to generally lie within inner radiating element 31. In this non-limiting embodiment of the invention linear slot 66 had a length that was generally equal to slot segment 63, and linear slot 66 extended generally parallel to slot segment 63.

Linear slot 66 lies in a common region of what can be called a slot-discontinuity within C-shaped slot 17, this slot-discontinuity being shared by the two metal stubs 33 and 34, and with one edge of linear slot 66 lying adjacent to the second shorting post 52 of inner radiating element 31. Linear slot 66 is also a means of ensuring a physical separation between the two metal stubs 33 and 34.

When the first metal stub 34 is considered to be a virtual feed for inner radiating element 31, the second metal stub 33 acts as a tuning element for inner radiating element 31. It is also possible to visualize that linear slot 66 enables inner radiating element 31 to have two feeds 33 and 34 which lie on two opposite sides of the shorting post 52 for inner radiating element 31.

Linear slot 66, being common to both outer radiating element 32 and inner radiating element 31, can also be equivalently termed as a closed coupling slot 66. The size and the position of linear slot 66 is an additional parameter to optimize the influence of the close proximity of inner radiating element 31 to complement the resonance characteristics of outer radiating element 32, and vice versa.

With reference to the two metal stubs 33 and 34, one can treat one of these two metal stubs as a matching stub for inner radiating element 31, whereupon the other metal stub can be considered to be a virtual feed for inner radiating element 31. In addition, the two metal stubs 33 and 34 can be visualized as two virtual feeds to inner radiating element 31, with

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shorting post 52 being located between the two metal stubs 33 and 34. However, both of the metal stubs 33 and 34 comprise matching or tuning stubs for outer radiating element 32.

As a feature of the invention, composite radiating element 14 of two-PIFA assembly 10 in accordance with the invention includes a number of reactive (capacitive) metal tuning plates or stubs that extend downward from the top surface of composite radiating element 14 to locations that are closely adjacent to, but spaced from, the top surface of ground plane element 11.

More specifically, and with reference to FIGS. 1 and 2, composite radiating element 14 includes a first metal plate 70 that is bent downward about 90-degrees from the side edge 21 of composite radiating element 14, and a second metal plate 71 that is bent downward about 90-degrees from the side edge 25 of composite radiating element 14.

When the two-PIFA assembly 10 is assembled, metal plate 71 lies closely adjacent to, or abuts against, the sidewall 39 of dielectric carriage 37, and metal plate 70 lies closely adjacent to, or abuts against, the opposite sidewall 41 of dielectric carriage 37.

In addition, and with reference to FIG. 2, composite radiating element 14 includes a third metal plate 72 that is bent downward about 90-degrees from the radiating edge 23 of composite radiating element 14. When two-PIFA assembly 10 is assembled, metal plate 72 lies closely adjacent to, or abuts against, the sidewall 40 of dielectric carriage 37.

Metal plate 70 acts as a capacitive loading plate for composite radiating element 14, and it controls the resonant characteristics of the upper resonant band without affecting the response of the lower band. Metal plate 71 is another means of providing capacitive loading of composite radiating element 14. Metal plate 71 primarily controls the resonant characteristics of the lower resonant band, and it exhibits minor effects on the response of the upper resonant band. Metal plate 72 functions as a capacitive loading element for composite radiating element 14 that controls the resonance characteristics of both the lower and the upper resonant bands.

FIG. 3a is another showing of the three above-described slots that are formed in composite radiating element 14, i.e. C-shaped slot 17, L-shaped slot 60, and linear slot 66.

Conceptually, FIG. 3a shows a composite-slot that is formed by a combination of C-shaped slot 17 (see FIG. 3c) and the slot segment 63 of L-shaped slot 60 (see FIG. 3b) that extends parallel to the minor axis 13 of ground plane 11 (see FIG. 1), wherein the three slot segments 26, 63 and 18 are generally aligned and extend parallel to the major axis 12 of ground plane 11. These three slot segments are located a distance 57 of about 0.119 inch from the non-radiating edge 19 of composite radiating element 14.

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As illustrated in FIG. 3c, the two metal stubs 33 and 34 are spaced apart and they transform what would have been a continuous-slot into the discontinuous C-shaped slot 17. Linear slot 66 lies between the two metal stubs 33 and 34, and linear slot 66 appears to be a displaced-portion of such a continuous-slot.

As shown in FIG. 3b, the length of slot segment 62 of L-shaped slot 60 is chosen such that the edge 89 of slot segment 63 is at a pre-determined distance from the radiating edge 91 (see FIG. 3c) of linear slot 66.

Alignment of the two metal stubs 33 and 34, visa vis segment 63 of L-shaped slot 60, allow linear slot 66 to be of a length equal to that of segment 63 of L-shaped slot 60. This results in the location of linear slot 66 in the close vicinity of an active L-shaped slot 60, wherein the term active implies that L-shaped slot 60 has an open end 61 along an edge of composite radiating element 14.

In general, L-shaped slot 60, whose open end 61 lies on the edge 19 of composite radiating element 14 that contains FIG. 1's feed post 45 and shorting post 50, provides a more rapid response than a slot that does not have an open end, or whose open end is along an axis that is perpendicular to an edge that contains the PIFA's feed and shorting posts.

In summary, the "PIFA within a PIFA", virtual two-PIFA assembly of this invention, having response in both cellular and non-cellular resonant frequency bands, is achieved by providing a composite radiating element having a composite slot that defines an inner radiating element and an outer radiating element within the composite radiating element, having one physical RF feed post that is connected to the outer radiating element, having a virtual feed that connects the one physical feed post to the inner radiating element, having a first shorting post that connects the outer radiating element to a ground plane element, and having a second shorting post that connects the inner radiating element to the ground plane element.

The invention provides a single-feed multi-band virtual two-PIFA-assembly that is constructed and arranged for global cellular communications, including the AMPS/GSM/DCS/PCS frequency bands. The two-PIFA construction and arrangement of this invention provides a "PIFA within a PIFA" wherein the radiating element of one PIFA is inserted into the radiating element of another PIFA, wherein the physical separation between the two PIFA radiating elements provide for very nearly independent control of the multiple resonant frequency bands of the two individual PIFAs that are within two-PIFA assembly.

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The combination of, and the physical location of, a generally L-shaped slot and a generally C-shaped slot, along with two metal stubs that connect the two slots, facilitates tuning the resonant frequencies of the two PIFAs to desired frequency bands.

The physical position of the single feed post, the size and position of first shorting post for the outer radiating element, the size and position of the metal stub that acts as a tuning element for the inner radiating element, the position and dimensions of the L-shaped slot on the outer radiating element, the position and dimensions of the C-shaped slot on the inner radiating element, the virtual feed for the inner radiating element, as well as the position and the size of the shorting post for the inner radiating element, provide an impedance match for the multi band performance of the two-PIFA assembly wherein multi band impedance matching is achieved without the need for an external matching network.

Single-feed multi-band two-PIFA assemblies in accordance with the present invention provide multiple resonant frequencies having utility in both cellular and non-cellular applications, wherein a single, unitary, two-PIFA assembly provides a "PIFA-within-a PIFA" construction and arrangement, and wherein it is relative ease to control the resonant characteristics of the two-antenna assembly so that the two-antenna assembly in accordance with this invention exhibits resonance performance that is adequate for global cellular communication, including the AMPS/GSM/DCS/PCS frequency bands, without requiring a switch or an external matching network.

From the structural point of view, a multi-band two-PIFA assembly in accordance with the invention requires only the addition of one element, i.e. the above-described second shorting post for the inner radiating element, and the composite radiating element that is within the multi-band two-PIFA assembly is amenable to large-scale manufacturing simply by punching or cutting, and then bending, a single piece of metal to form the various above-described slots that are formed within the composite radiating element, and the above-described feed post, shorting post and metal plates that protrude from the composite radiating element.

Single-feed multi-band two-PIFA assemblies in accordance with the invention resonate in the AMPS/PCS frequency bands and the GSM/DCS frequency bands, as well as in the GPS frequency band, and they have utility for use in global cellular handsets and in system applications that require simultaneous cellular and non-cellular operation.

While the invention has been described in detail while making reference to an embodiment thereof, it is known that others skilled in the art will, upon learning of this invention, readily visualize yet other embodiments that are within the spirit and scope of this

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invention. Thus, this detailed description is not to be taken as a limitation on the spirit and scope of this invention.

What is claimed is:

1. A method of providing an antenna assembly, comprising the steps of:

providing a metal ground plane element;

providing a metal plate;

forming a slot in said metal plate in a manner to produce an outer metal radiating element and an inner metal radiating element that is connected to said outer metal radiating element by at least one metal stub;

supporting said metal plate above said metal ground plane element;

providing a metal feed post extending from a portion of said outer metal radiating element;

connecting a feed to said metal feed post;

providing a first metal shorting post extending from said portion of said outer metal radiating element and connected to said metal ground plane element;

said first metal shorting post being spaced from said metal feed post; and

providing a second metal shorting post extending from said inner metal radiating element and connected to said metal ground plane element.

2. The method of claim 1 wherein said metal ground plane element and said metal plate are generally parallel.

3. The method of claim 2 wherein said metal ground plane element has a larger planar area than said metal plate, and wherein an entire area of said metal plate is located over said metal ground plane element.

4. The method of claim 3 wherein said metal feed post is associated with said at least one metal stub such that said at least one metal stub functions as an virtual metal feed post for said inner metal radiating element.

5. The method of claim 4 wherein said at least one metal stub additionally functions as a matching/tuning element for said outer radiating element.

6. The method of claim 5 wherein said slot is a discontinuous slot, wherein a first metal stub forms a first end of said discontinuous slot that is relatively close to said metal feed post, and wherein a second metal stub forms a second end of said discontinuous slot that is relatively close to said first metal shorting post.

7. The method of claim 6 wherein said first metal stub functions as a virtual feed for said inner radiating element, wherein said second metal stub functions as a

matching/tuning element for said inner radiating element, and wherein said first and second metal stubs function as matching/tuning elements for said outer radiating element.

8. The method of claim 6 wherein said outer metal radiating element and said inner metal radiating element lie in a common plane that is parallel to a plane of said metal ground plane element.

9. The method of claim 8 wherein said first and second metal stubs cantilever-support said inner metal radiating element.

10. The method of claim 9 including the step of:

providing a generally rigid dielectric carriage having a plurality of sidewalls whose top edges define a top surface that engages said metal plate, and whose a bottom edges define a bottom surface that engages said metal ground plane element.

11. The method of claim 10 wherein said antenna assembly contains a first planar inverted-F antenna including said outer metal radiating element, and a second planar inverted-F antenna including said inner metal radiating element.

12. The method of claim 10 including the step of:

providing a generally L-shaped slot between said first and second metal stubs;

said generally L-shaped slot having an open end located between said first metal shorting post and said metal feed post.

13. The method of claim 12 including the step of:

providing at least one metal plate extending from said outer metal radiating element toward said metal ground plane element;

said at least one metal plate having an end that is spaced above said metal ground plane element.

14. The method of claim 13 wherein said at least one metal plate closely abuts at least one sidewall of said dielectric carriage to comprise at least one reactive loading plate for said antenna assembly.

15. The method of claim 14 including the step of:

providing a further slot in said inner metal radiating element at a location generally intermediate said first and second metal stubs.

16. The method of claim 15 wherein said antenna assembly contains a first planar inverted-F antenna including said outer metal radiating element, and a second planar inverted-F antenna including said inner metal radiating element.

17. The method of claim 16 wherein said first metal stub functions as a virtual feed for said inner radiating element, wherein said second metal stub functions as a

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matching/tuning element for said inner radiating element, and wherein said first and second metal stubs function as matching/tuning elements for said outer radiating element.

18. A method of providing a unitary PIFA-within-a-PIFA assembly, comprising the steps of:

providing a planar ground plane element;

providing a planar composite radiating element;

forming a generally C-shaped slot within said composite radiating element to produce an inner radiating element and an outer radiating element that generally surrounds said inner radiating element and is coplanar with said inner radiating element;

said generally C-shaped slot having a metal slot-discontinuity that connects said inner radiating element to said outer radiating element;

providing a generally rigid dielectric carriage for supporting said composite radiating element generally parallel to said ground plane element;

providing a feed post extending from an edge-portion of said outer radiating element;

providing a first shorting post extending from said edge-portion of said outer radiating element and connected to said ground plane element;

said first shorting post being spaced from said feed post; and

providing a second shorting post extending from said inner radiating element and connected to said ground plane element.

19. The method of claim 18 wherein said metal slot-discontinuity is located adjacent to said edge-portion of said outer radiating element.

20. The method of claim 19 including the step of:

providing a generally L-shaped slot generally within said metal slot-discontinuity;

said generally L-shaped slot forming two metal stubs within said slot-discontinuity that connect said inner radiating element to said outer radiating element;

said generally L-shaped slot having an open end located on said edge-portion of said outer radiating element between said feed post and said first shorting post.

21. The method of claim 20 including the steps of:

providing that a first of said two metal stubs is constructed and arranged to form a virtual feed for said inner radiating element;

providing that a second of said two metal stubs is constructed and arranged to form a matching/tuning element for said inner radiating element; and

providing that said first and second metal stubs are constructed and arranged to form matching/tuning elements for said outer radiating element.

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22. The method of claim 20 including the step of:

providing at least one metal plate extending from said outer radiating element toward said ground plane element;

said at least one metal plate having an end that is spaced from said ground plane element; and

said at least one metal plate being closely associated with said dielectric carriage and comprising at least one reactive loading plate.

23. The method of claim 22 including the step of:

providing a generally linear slot in said composite radiating element within said inner radiating element and generally intermediate said first and second metal stubs.

24. The method of claim 23 wherein said composite radiating element is formed by the steps of:

providing a generally flat metal plate that occupies a plane;

processing said flat metal plate to form said generally C-shaped slot, said first and second metal stubs and said generally L-shaped slot therein, to form said generally linear slot therein, to form said feed post therein, to form said first shorting post therein, and to form said at least one plate therein; and

bending said feed post, said first shorting post and said at least one metal plate in a common direction relative to said plane.

25. The method of claim 24 wherein said feed post, said first shorting post and said at least one plate are bent about 90-degrees relative to said plane.

26. The method of claim 25 including the step of:

constructing and arranging said unitary PIFA-within-a-PIFA assembly for resonance in the AMPS, the PCS, the GSM and the DCS frequency bands.

27. The method of claim 26 including the step of:

additionally constructing and arranging said unitary PIFA-within-a-PIFA mechanical assembly for resonance in the GPS frequency band.

28. A unitary two-antenna assembly having a single feed port and providing multiple frequency response, comprising:

a metal ground plane element;

a metal sheet physically that is spaced from and generally parallel to said metal ground plane element;

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a generally C-shaped slot formed in said metal sheet forming in said metal sheet into an inner radiating element, an outer radiating element, and a metal stub connecting said inner radiating element to said outer radiating element;

said metal stub forming a discontinuity in said generally C-shaped slot;

a metal feed post extending from a first portion of said outer radiating element;

a first metal shorting post extending from said first portion of said outer radiating element having an end connected to said ground plane element;

said first metal shorting post being spaced from said metal feed post; and

a second metal shorting post extending from a portion of said inner radiating element that is generally adjacent to said metal stub having an end connected to said ground plane element.

29. The unitary two-antenna assembly of claim 28 including:

a plurality of metal plates extending from portions of said outer radiating element, each of said metal plates having an end spaced from said ground plane element.

30. The unitary two-antenna assembly of claim 29 wherein said metal feed post, said first metal shorting post, and said plurality of metal plates are integral parts of said metal sheet.

31. The unitary two-antenna assembly of claim 30 wherein said second metal shorting post is a disjoint metal post having one end secured to said inner radiating element and having an opposite end secured to said ground plane element.

32. The unitary two-antenna assembly of claim 28 including:

a generally L-shaped open slot formed in said metal sheet, said generally L-shaped open slot having an open end located on said first portion of said outer radiating element and between said first metal shorting post and said metal feed post.

33. The unitary two-antenna assembly of claim 32 including:

a dielectric carriage having a top surface cooperating with said inner and outer radiating elements, having a bottom surface cooperating with said ground plane element, and having a first sidewall cooperating with said metal feed post and said first metal shorting post.

34. The unitary two-antenna assembly of claim 33 including:

a plurality of metal plates extending from of said outer radiating element, in a direction toward said ground plane element, each of said metal plates having an end that is spaced from said ground plane element, said plurality of metal plates cooperating with other

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sidewalls of said dielectric carriage so as to form a plurality of reactive plates for said two-antenna assembly.

35. The unitary two-antenna assembly of claim 28 including:

a slot formed in said metal stub operating to divide said metal stub into two physically spaced metal stubs that connect said inner radiating element to said outer radiating element;

at least one of said two metal stubs providing a virtual feed to said inner radiating element; and

said two metal stubs providing a matching/tuning function for said outer radiating element.

36. The unitary two-antenna assembly of claim 35 wherein a first of said two metal stubs provides said virtual feed to said inner radiation element, and wherein a second of said two metal stubs provides a matching/tuning function for said inner radiating element.

37. A unitary PIFA-within-a-PIFA assembly having a single feed port and providing response to a plurality of frequency bands, comprising:

a dielectric carriage having four sidewalls that define a rectangular bottom surface having four orthogonal edges and a rectangular top surface having four orthogonal edges, said bottom surface being generally parallel to said top surface, and said four sidewalls extending generally perpendicular between said four orthogonal edges of said top surface and said bottom surface;

a rectangular metal ground plane element having four orthogonal edges;

said ground plane element having a top surface, a short axis, and a long axis that extends perpendicular to said short axis;

said ground plane element engaging said bottom surface of said dielectric carriage with a first sidewall of said dielectric carriage generally coincident with a first edge of said ground plane element that extends generally parallel to said short axis of said ground plane element, and with a second and a third sidewall said dielectric carriage generally coincident with opposite edges of said ground plane element that extend generally parallel to said long axis of said ground plane element;

a rectangular metal composite radiating element of generally the same size as said top surface of said dielectric carriage;

said composite radiating element having a non-radiating edge, a radiating edge that extends generally parallel to said non-radiating edge, and having a first and a second parallel side edge that extends generally perpendicular to said non-radiating edge and said radiating edge;

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said composite radiating element engaging said top surface of said dielectric carriage with said radiating edge of said composite radiating element generally coincident with said first edge of said ground plane element, and with said first and second side edges of said composite radiating element generally coincident with said opposite edges of said ground plane element;

a metal feed post extending from said non-radiating edge of said composite radiating element;

a first metal shorting post extending from said non-radiating edge of said composite radiating element and spaced from said feed post;

said first shorting post extending in a direction toward said ground plane element and having an end thereof connected to said ground plane element;

a generally C-shaped slot in said radiating element;

said generally C-shaped slot having a first slot-segment that lies adjacent to said non-radiating edge of said composite radiating element, said first slot-segment having a closed end;

said generally C-shaped slot having a second slot-segment extending from said first slot-segment and lying adjacent to a first side edge of said composite radiating element;

said generally C-shaped slot having a third slot-segment extending from said second slot-segment and lying adjacent to said radiating edge of said composite radiating element;

said generally C-shaped slot having a fourth slot-segment extending from said third slot-segment and lying adjacent to an opposite side edge of said composite radiating element;

said generally C-shaped slot having a fifth slot-segment extending from said fourth slot-segment and lying adjacent to a non-radiating edge of said composite radiating element, and in alignment with said first slot-segment;

said fifth slot-segment having a closed end that is spaced from said closed end of said first slot-segment to define a discontinuity-area in said generally C-shaped slot;

a second shorting post extending from a portion of said composite radiating element that is on a side of said discontinuity-area opposite said non-radiating edge of said composite radiating element;

said second metal shorting post extending in a direction toward said ground plane element; and

said second shorting post having an end thereof connected to said ground plane element.

38. The unitary PIFA-within-a-PIFA assembly of claim 37 including:

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an generally L-shaped slot in said discontinuity-area, said generally L-shaped slot having an open end that is located on said non-radiating edge between said shorting post and said first feed post, having a first slot-segment that extends generally perpendicular to said non-radiating edge, and having a second slot-segment that extends from said first slot-segment and generally parallel to said non-radiating edge.

39. The unitary PIFA-within-a-PIFA assembly of claim of claim 38 including:

a generally linear slot in said discontinuity-area adjacent to said second slot-segment of said generally L-shaped slot and extending generally parallel to said non-radiating edge.

40. The unitary PIFA-within-a-PIFA assembly of claim 39 including:

a first metal plate extending from said first side of said composite radiating element in a direction toward said ground plane element, said first metal plate having an end spaced from said ground plane element, and said first metal plate cooperating with a sidewall of said dielectric carriage.

41. The unitary PIFA-within-a-PIFA assembly of claim 40 including:

a second metal plate extending from said opposite side of said composite radiating element in a direction toward said ground plane element, said second metal plate having an end spaced from said ground plane element, and said second metal plate cooperating with a sidewall of said dielectric carriage.

42. The unitary PIFA-within-a-PIFA assembly of claim 41 including:

a third metal plate extending from said radiating edge of said composite radiating element, in a direction toward said ground plane element, said third metal plate having an end spaced from said ground plane element, and said third metal plate cooperating with a sidewall of said dielectric carriage.

43. The unitary PIFA-within-a-PIFA assembly of claim 42 wherein said feed post, said first shorting post, and said first, second and third plates are integral parts of said composite radiating element, and wherein said second shorting post is a disjoint member having one end secured to said composite radiating element and having an opposite end secured to said ground plane element.

44. The unitary PIFA-within-a-PIFA assembly of claim 37 wherein said generally C-shaped slot divides said composite radiating element into an inner radiating element and an outer radiating element that surrounds said inner radiating element, including:

a slot in said discontinuity-area operating to form said discontinuity area into two spaced stubs that physically connect said inner radiating element to said outer radiating element;

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a first of said stubs providing a virtual feed for said inner radiating element;

a second of said stubs providing a matching/tuning function for said inner radiating element; and

said first and second stubs providing a matching/tuning function for said outer radiating element.

45. A unitary assembly providing two PIFAs within a physical volume usually occupied by one PIFA, comprising:

a metal radiating element supported above a metal ground plane element;

a generally C-shaped slot in said radiating element dividing said radiating element into an outer metal radiating element and an inner metal radiating element;

said generally C-shaped slot establishing a metal slot-discontinuity-area within said radiating element that physically and electrically connect said outer radiating element to said inner radiating element;

a metal feed post connected to said outer radiating element;

a first metal shorting post connecting said outer radiating element to said ground plane element; and

a second metal shorting post connecting said inner radiating element to said ground plane element.

46. The unitary mechanical assembly of claim 45 including:

a generally L-shaped slot located generally in said slot-discontinuity-area operating to divide said slot-discontinuity-area into two spaced metal stubs that physically and electrically connect said outer radiating element to said inner radiating element.

47. The unitary mechanical assembly of claim 46 including:

a generally linear slot located generally in said slot-discontinuity-area.

48. The unitary mechanical assembly of claim 47 including:

at least one metal plate extending from said radiating element toward said ground plane element, but out of physical contact with said ground plane element.

49. The unitary assembly of claim 48 wherein a first of said two metal stubs provides a virtual feed to said inner radiating element, wherein a second of said two metal stubs provides a matching and/or tuning function for said inner radiating element, and wherein said two metal stubs provide a matching and/or tuning function for said outer radiating element.

50. The unitary assembly of claim 45 including:

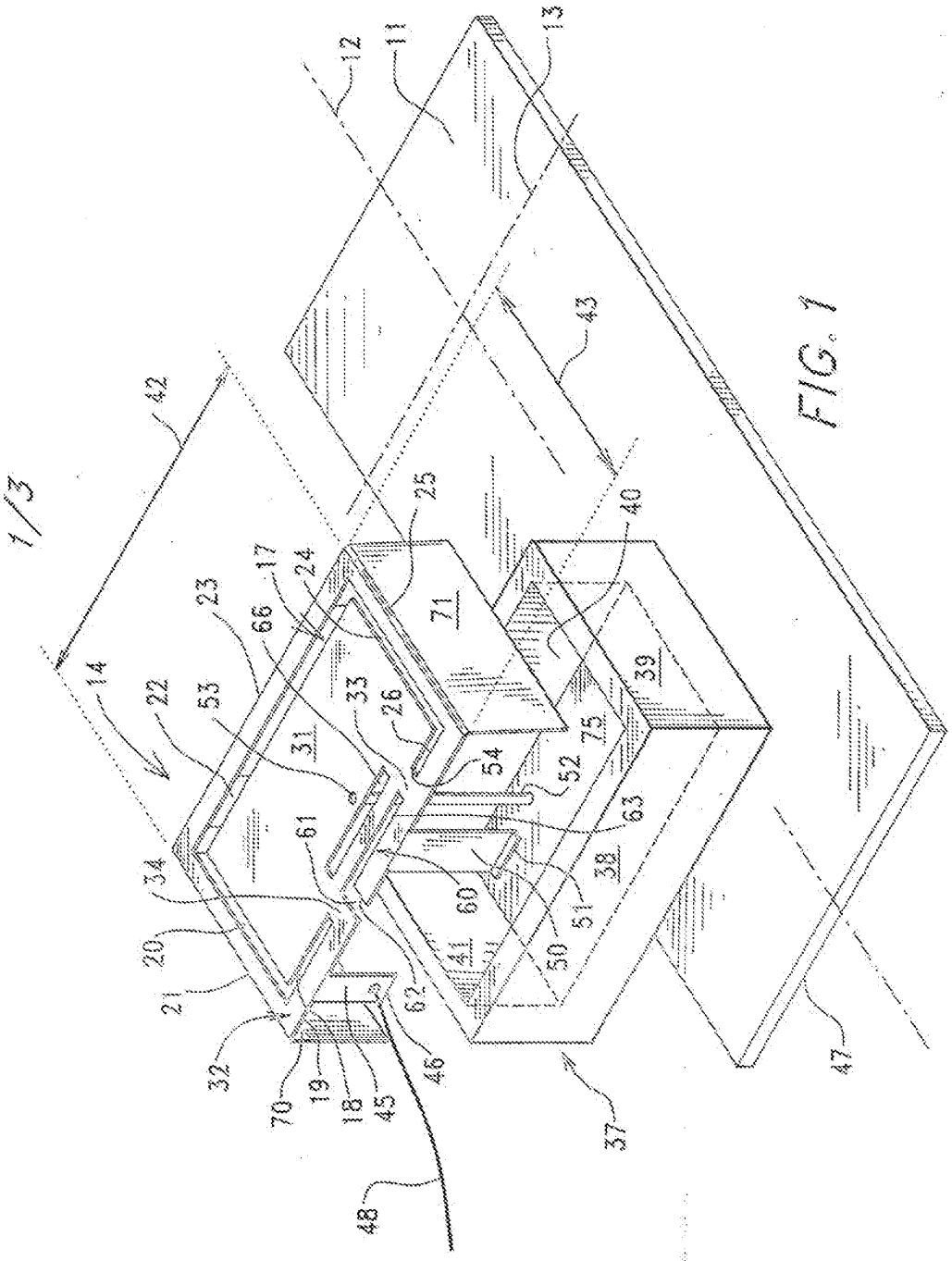
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a slot located generally in said slot-discontinuity-area operating to divide said slot-discontinuity-area into two spaced metal stubs that physically and electrically connect said outer radiating element to said inner radiating element;

at least one of said two metal stubs provide virtual feed to said inner radiating element; and

said two metal stubs provide a matching/tuning function to said outer radiating element.

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FIG. 1
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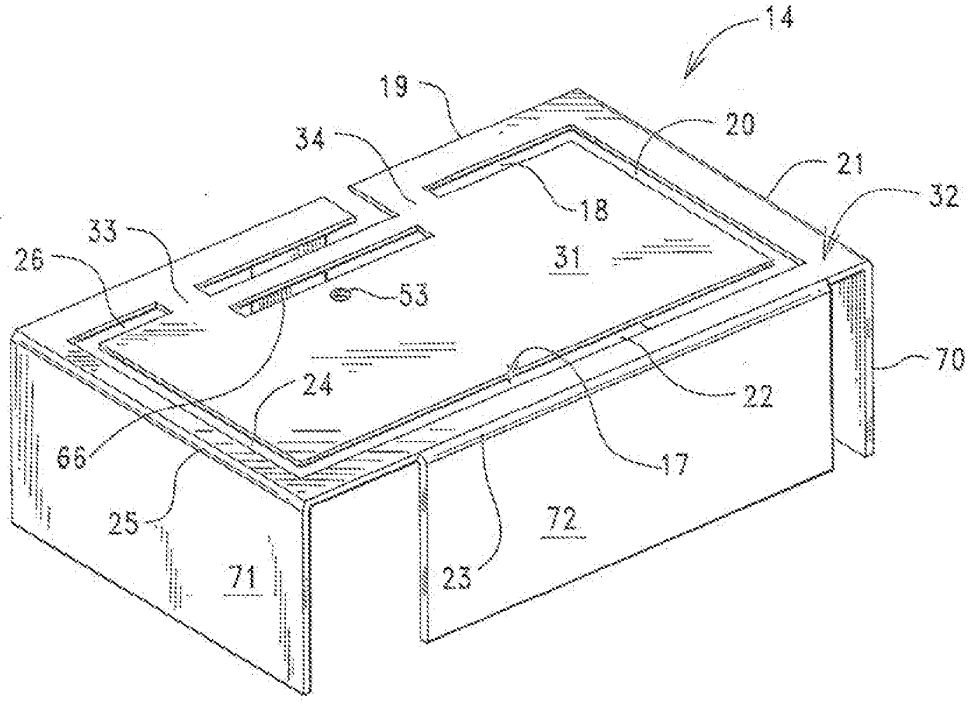


FIG. 2

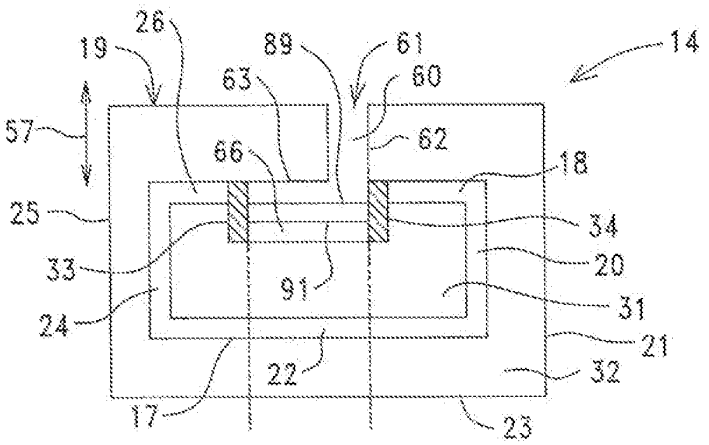


FIG. 3a

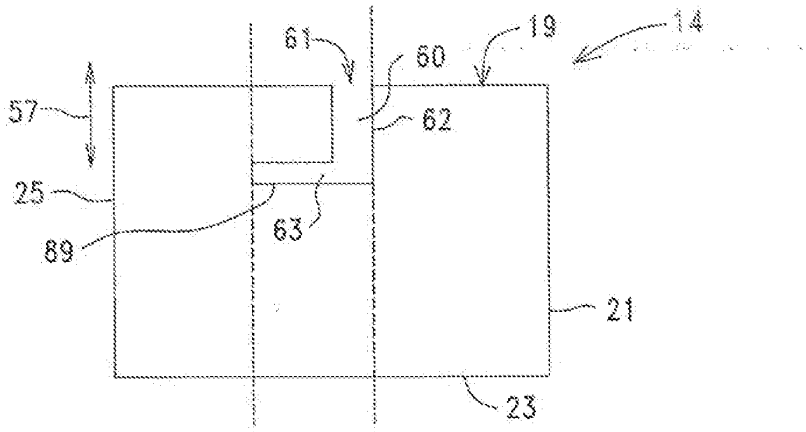


FIG. 3b

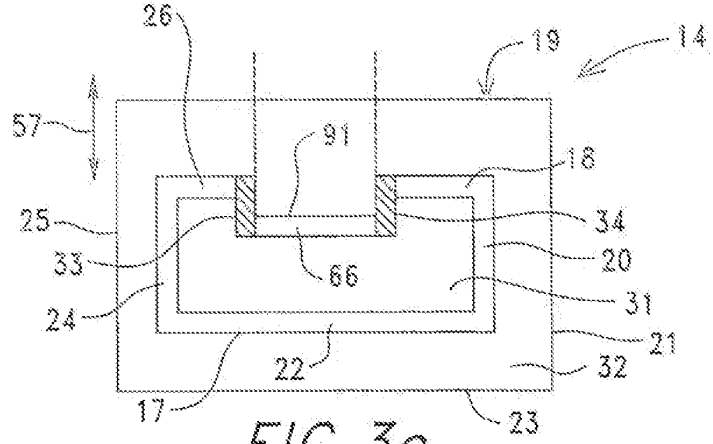


FIG. 3c

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
20 November 2003 (20.11.2003)

PCT

(10) International Publication Number
WO 03/096475 A1

(51) International Patent Classification⁷: H01Q 1/24, 13/10, 9/04, 13/16

(21) International Application Number: PCT/IB03/01868

(22) International Filing Date: 29 April 2003 (29.04.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0210601.1 9 May 2002 (09.05.2002) GB

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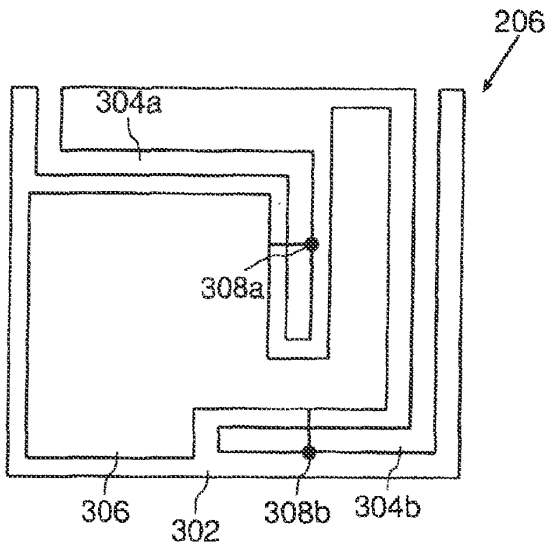
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: ANTENNA ARRANGEMENT AND MODULE INCLUDING THE ARRANGEMENT



(57) Abstract: An antenna arrangement comprises a ground conductor (302) incorporating two slots (304a,304b) having an electrically small separation and means (308a,308b) for coupling a transceiver to each slot to enable the ground conductor to function as two substantially independent antennas. Such a device enables efficient diversity performance to be obtained from a significantly smaller volume than known antenna arrangements. In one embodiment the ground conductor, slots and transceiver are integrated in a module (206) adapted for connection to a further ground conductor which provides the majority of the antenna area. The further conductor would typically be a printed circuit board ground plane or mobile phone handset. Matching and broadbanding circuitry may conveniently be incorporated in the module. By varying the area of the connections between the module and the further ground conductor, the resonant frequencies of the slots can be modified.

WO 03/096475 A1

BNSDOCID: <WO_____03096475A1_1_>

DESCRIPTION

ANTENNA ARRANGEMENT AND MODULE INCLUDING THE ARRANGEMENT

The present invention relates to an antenna arrangement comprising a ground conductor and means for coupling a transceiver to the ground conductor, and further relates to a radio module comprising the transceiver and the antenna arrangement.

Wireless terminals, such as mobile phone handsets, typically incorporate either an external antenna, such as a normal mode helix or meander line antenna, or an internal antenna, such as a Planar Inverted-F Antenna (PIFA) or similar.

Such antennas are small (relative to a wavelength) and therefore, owing to the fundamental limits of small antennas, narrowband. However, cellular radio communication systems typically have a fractional bandwidth of 10% or more. To achieve such a bandwidth from a PIFA for example requires a considerable volume, there being a direct relationship between the bandwidth of a patch antenna and its volume, but such a volume is not readily available with the current trends towards small handsets. Hence, because of the limits referred to above, it is not feasible to achieve efficient wideband radiation from small antennas in present-day wireless terminals.

A further problem with known antenna arrangements for wireless terminals is that they are generally unbalanced, and therefore couple strongly to the terminal case. As a result a significant amount of radiation emanates from the terminal itself rather than the antenna. A wireless terminal in which an antenna feed is directly coupled to the terminal case, thereby taking advantage of this situation, is disclosed in our International patent application WO 02/13306. When fed via an appropriate matching network the terminal case, or another ground conductor, acts as an efficient, wideband radiator. A modification of this arrangement in which the antenna feed is coupled to the

terminal case via a slot is disclosed in our pending international patent application WO 02/95869 (unpublished at the priority date of the present invention).

In many applications it is desirable for a wireless terminal to have two independent antennas, to enable the use of antenna diversity techniques. However, known antenna diversity arrangements typically occupy a significant volume in order for the antennas to have sufficient electrical separation to provide uncorrelated signals.

An object of the present invention is to provide a compact antenna diversity arrangement for a wireless terminal.

According to a first aspect of the present invention there is provided an antenna arrangement comprising a ground conductor incorporating two slots having an electrically small separation and means for coupling a transceiver to each slot, thereby enabling the ground conductor to function as two substantially independent antennas.

The diversity performance of the arrangement may be optimised by arranging for the slots to be substantially orthogonal (by which it is meant, in the case of slots having one open end, that portions of each slot which are a similar distance (measured along the slot) from their respective open ends are substantially orthogonal). It may also be optimised by applying capacitive loading to the slots and applying a different phase shift between the transceiver and each slot. The electrically small separation will typically be less than half a wavelength at operational frequencies of the arrangement.

According to a second aspect of the present invention there is provided a radio module comprising a ground conductor incorporating two slots having an electrically small separation, a transceiver, means for coupling the transceiver to each slot and means for coupling the ground conductor to a further ground conductor, thereby enabling the combination of the ground conductor and the further ground conductor to function as two substantially independent antennas.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 shows a model of an asymmetrical dipole antenna, representing the combination of an antenna and a wireless terminal;

Figure 2 is a plan view of a Radio Frequency (RF) module mounted on a ground conductor;

Figure 3 is a plan view of an RF module comprising a slotted ground plane;

Figure 4 is a plan view of a practical embodiment of an RF module;

Figure 5 is a graph of measured return loss S_{11} in dB against frequency f in MHz for the RF module shown in Figure 4;

Figure 6 is a plan view of an RF module comprising a ground plane having two substantially orthogonal slots; and

Figure 7 is a plan view of an RF module comprising a ground plane having two parallel, capacitively loaded slots.

In the drawings the same reference numerals have been used to indicate corresponding features.

Our International patent application WO 02/13306 discloses an antenna arrangement in which the case of a wireless terminal, or another ground conductor forming part of the terminal, is fed via an appropriate matching network and acts as an efficient, wideband radiator.

In summary, it was shown in WO 02/13306 that the combination of an antenna and a wireless terminal (for example a mobile phone handset) can be regarded as an asymmetrical dipole. Figure 1 shows such a model of the impedance seen by a transceiver, in transmit mode, in a wireless handset at its antenna feed point. The first arm 102 of the asymmetrical dipole represents the impedance of the antenna and the second arm 104 the impedance of the handset, both arms being driven by a source 106. As shown in the figure, the impedance of such an arrangement is substantially equivalent to the sum of the impedance of each arm 102,104 driven separately against a virtual ground

108. The model is equally valid for reception when the source 106 is replaced by an impedance representing that of the transceiver.

It was also shown in WO 02/13306 that the antenna impedance could be replaced by a physically-small capacitor coupling the antenna feed to the handset. In one embodiment the capacitor was a parallel plate capacitor having dimensions of 2×10×10mm on a handset having dimensions of 10×40×100mm. By careful design of the handset, the resultant bandwidth could be much larger than with a conventional antenna and handset combination. This is because the handset acts as a low Q radiating element (simulations show that a typical Q is around 1), whereas conventional antennas typically have a Q of around 50.

A problem with the use of a parallel plate capacitor to couple a transceiver to a ground plane is that it requires a significant volume (even if this volume is much less than that needed for a PIFA). As part of the current trend towards ever-smaller wireless terminals, low-profile modules are being developed including the RF circuitry required for a device (such as a mobile phone or Bluetooth terminal). Such modules are typically shielded by being enclosed in a metallic container, although such shielding is not always necessary. The addition of a capacitor plate of the dimensions indicated above can more than double the volume occupied by such a module by doubling its height, which is undesirable.

This problem was solved, as disclosed in our pending International patent application WO 02/95869, by feeding RF power from a transceiver to a ground plane across a slot in the ground plane. This arrangement is illustrated with reference to Figures 2 and 3, which are respectively plan views of a RF module mounted on a ground conductor and of an RF module comprising a slotted ground plane. An RF module 206 is mounted on a Printed Circuit Board (PCB) having a rectangular ground plane 202 with a rectangular cut-out 204 (shown dashed). The module 206 also comprises a ground plane 302, having dimensions slightly larger than the cut-out 204 to enable the two ground planes 202,302 to be electrically connected. The module's ground plane 302 incorporates a slot 304 which is approximately a quarter wavelength long at

the operational frequency of the module 206. The module includes RF circuitry 306 (not shown in detail) and a connection 308 to the side of the slot 304 remote from the RF circuitry.

In operation as a transmitter, power from the RF circuitry 306 is fed across the slot and thence to the ground planes 302,202. In operation as a receiver, RF signals received by the ground planes 302,202 are extracted by means of the slot 304 and fed to the RF circuitry 306. Although such a feeding arrangement does not provide such a wide bandwidth as the capacitive coupling described in WO 02/13306, the arrangement still provides a wide bandwidth compared to conventional antennas, and the trade-off between volume and bandwidth will be appropriate for many applications.

The slot 304 may, as illustrated, be folded around the RF circuitry 306. It can be designed so that its resonant frequency is principally determined by the quarter wave slot resonance, while its bandwidth is determined by the combination of slot 304 and ground planes 302,202. Integration of the slot 304 in the module 206 enables tuning of its resonant frequency by varying the connections between the module's ground plane 302 and the PCB ground plane 202. Although the cut-out 204 in the PCB ground plane 202 is shown as being rectangular and of a similar size to the module 206, this is not essential. The only requirement is that the cut-out 204 is such that there is no metallisation on the PCB immediately beneath the slot 304 (and in practice that the cut-out 204 is larger than the slot 304 by at least as much as production tolerances and alignment errors, so that the effective slot dimensions are determined by the dimensions of the slot 304 in the module 206, and not by the dimensions of the cut-out 204). The location of the module 206 at the edge of the PCB, as shown, is convenient since the module is relatively remote from the remaining circuitry on the PCB but it remains straightforward to make connections to the module.

Figure 4 shows a plan view of a production embodiment of a RF module 206 having overall dimensions of approximately 15×13mm. This embodiment is manufactured by Philips Semiconductors, having a product number BGB100A, and is intended for use in Bluetooth applications. An L-shaped

ground conductor 302 incorporates an L-shaped slot 304. The slot is fed via a 1.5nH inductor connected to connection points 402,308 and a 3pF series capacitor connected to connection points 404,406. Further matching circuitry comprising a 1.3nH series inductor and a 1.8pF shunt capacitor is connected between the series capacitor and a 50Ω feed. Other RF circuitry 306, not shown, is included in the area enclosed by the dashed lines. This circuitry includes a plurality of ground connections so that, when mounted on a PCB, substantially the whole of the area enclosed by the dashed lines can be considered as ground conductor.

In this embodiment the PCB ground plane is close to a half wavelength in dimension, resulting in good bandwidth. Figure 5 is a graph of measured return loss S_{11} of the module of Figure 4, in each case for frequencies between 1500 and 3500MHz. The module 206 was mounted with the slot 304 opening onto the long edge of a PCB having dimensions 100×40mm, the module being located 25mm from the short edge of the PCB. The efficiency is greater than 80% and the return loss greater than 10dB over a bandwidth of more than 1GHz from 1900 to 2900MHz. Link test measurements have demonstrated adequate performance over a distance in excess of 10m, thereby meeting the requirements of the Bluetooth specification.

The present invention improves on the arrangement described above by providing two independent modes of operation, thereby enabling the ground planes 202,302 to function as if they were two independent antennas. In conventional antenna diversity arrangements provision of a diversity arrangement would require two antennas separated by a significant fraction of a wavelength, and could not therefore be provided in a compact module 206 such as that described above. However, in a module made in accordance with the present invention, a diversity arrangement is possible in such a small area.

Figure 6 is a plan view of a first embodiment of a module 206 made in accordance with the present invention, the module comprising a ground conductor 302 and first and second slots 304a,304b. The slots 304a,304b are configured to be substantially orthogonal to one another at the same field/current points, i.e. at corresponding points along their length measured

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from their open ends. This is most critical at the shorted ends of the slots 304a,304b, where the largest unopposed currents are found. As a result of this orthogonality, each slot sets up different current distributions on the PCB ground plane 202, leading to different radiation and polarisation patterns and therefore independent reception of multipath components. Hence, signals transmitted or received via each slot are substantially uncorrelated.

The module 206 includes RF circuitry 306, which can occupy the area of the module not taken up by the slots 304a,304b. In operation, power from the RF circuitry 306 is fed across the slots to respective connection points 308a,308b on the sides of the slots 304a,304b remote from the bulk of the RF circuitry 306. For Bluetooth applications, the module 206 could be of similar size to that shown in Figure 4, with each of the slots 304a,304b having a length similar to that in the Figure 4 embodiment. While the slots 304a,304b should be approximately a quarter of a wavelength long in principle, the presence of the module substrate allows this to be reduced to perhaps 20mm (at 2.4GHz).

An alternative arrangement is shown in Figure 7, which is a plan view of a second embodiment of a module 206 made in accordance with the present invention. In this embodiment the slots 304a,304b are loaded by respective capacitors 702a,702b, which allows them to be shortened while maintaining the same resonant frequency. This allows the slots 304a,304b to be separated as far as possible within the footprint of the module 206, although this still represents a separation of only a tenth of a wavelength for the Bluetooth module referred to above. The cross-correlation between transmitted or received signals from each slot can be further reduced by appropriate phasing of the signals from each slot. The required phase shifts can be achieved by a variety of techniques including discrete phase shifting circuits, hybrid couplers, and switched parasitic loading.

Selection of suitable phasing for dipole antennas is discussed in our pending International patent application WO 01/71843. However, the techniques presented there are not directly applicable to the present invention because it relates to dipole antennas rather than slots, and also because in

embodiments of the present invention the slots 304a,304b share a common ground conductor 202,302.

Combinations of these two methods (orthogonal and capacitively-loaded slots) may be used to give diversity that is dependent on space, polarisation and radiation patterns (all of which are inter-related with such small slot separations). In this way, diversity can be achieved from a very small space, such as that available in an antenna-enabled RF module.

In some applications, dual band antennas may be required for use in multi-standard wireless communication equipment. Typical combinations are Bluetooth or IEEE 802.11b (WiFi) at 2.4GHz and IEEE 802.11a at 5GHz. Both of the IEEE standards support diversity. Dual band performance can be achieved by feeding the slots 304a,304b at single points and using dual band matching networks. However, in embodiments such as those presented above where the slots are contained within the radio module, it is advantageous to feed each slot 304a,304b at two different points and provide isolation via a multiplexing (switch or filter) network. Choosing the low frequency feed point to be close to an electric field null of the high frequency feed point can further enhance this isolation. For example, the low frequency feed point could be close to the shorted ends of the slots 304a,304b and the high frequency feed point closer to the open ends.

In addition to the polarisation diversity resulting from different current flow patterns in the ground conductors 302,202 in the embodiments shown in Figures 6 and 7, further polarisation diversity can be achieved in any embodiment by using slots 304a,304b (as described above) in conjunction with a conventional PIFA. The antennas can be located within the same volume (a very small RF module) but have substantially different polarisations. This is because the slots 304a,304b are embedded in the PCB rather than being fed against it. The PIFA will have the polarisation of the PCB, while the polarisation of the slots 304a,304b will depend on their orientation within the PCB. This can be arranged to provide orthogonality, which can be at least partially achieved without modification of the PIFA or slots. If the two antennas

couple too strongly a switch may also be provided across the slots when the PIFA is receiving.

As described above, the slots 304a,304b can either be incorporated into the ground plane 302 of an RF module 206 or a PCB ground plane 202. In the latter case, the RF components may or may not be provided in the form of a module 206. An advantage of incorporating the slots 304a,304b in the module 206 is that the feeds can be more precisely controlled, while matching, bandwidth broadening and/or multi-band operation can be realised in a well-controlled manner. It can be seen that there are significant advantages in fabricating an integrated module, which can then be connected to a PCB ground plane for improved radiation performance.

References above to an RF module 206 do not preclude the inclusion of other non-RF components in a module, such as for example baseband and device control circuitry. In the embodiments shown above, the slots 304a,304b were open-ended. However, slots closed at both ends can equally well be used if fed in a balanced manner.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of radio communications devices and component parts thereof, and which may be used instead of or in addition to features already described herein.

In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Further, the word "comprising" does not exclude the presence of other elements or steps than those listed.

CLAIMS

1. An antenna arrangement comprising a ground conductor (302) incorporating two slots (304a, 304b) having an electrically small separation and means (308a, 308b) for coupling a transceiver to each slot, thereby enabling the ground conductor to function as two substantially independent antennas.

2. An arrangement as claimed in claim 1, characterised in that one end of each slot (304a, 304b) is open and in that portions of each slot which are a similar distance from their respective open ends are substantially orthogonal.

3. An arrangement as claimed in claim 1 or 2, characterised in that capacitive loading is applied to the slots.

4. An arrangement as claimed in claim 1, 2 or 3, characterised in that means are provided for applying a different phase shift between the transceiver and each slot.

5. An arrangement as claimed in any one of claims 1 to 4, further comprising a planar inverted-F antenna, characterised in that the polarisations of the ground conductor and the planar antenna are significantly different.

6. A radio module (206) comprising a ground conductor (302) incorporating two slots (304a, 304b) having an electrically small separation, a transceiver, means (308a, 308b) for coupling the transceiver to each slot and means for coupling the ground conductor to a further ground conductor, thereby enabling the combination of the ground conductor and the further ground conductor to function as two substantially independent antennas.

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7. A module as claimed in claim 6, characterised in that means are provided for varying the connection area between the ground conductor and further ground conductor, thereby altering the operational frequency of the module.

8. A module as claimed in claim 6 or 7, characterised in that the transceiver is adapted for dual-band use and in that the means (308a, 308b) for coupling the transceiver to each slot comprises first and second connections to each slot, the first connection for use in a first frequency band and the second for use in a second frequency band.

9. An arrangement as claimed in claim 6, characterised in that the further ground conductor is a printed circuit board ground plane.

10. An arrangement as claimed in claim 6, characterised in that the further ground conductor is a handset case.

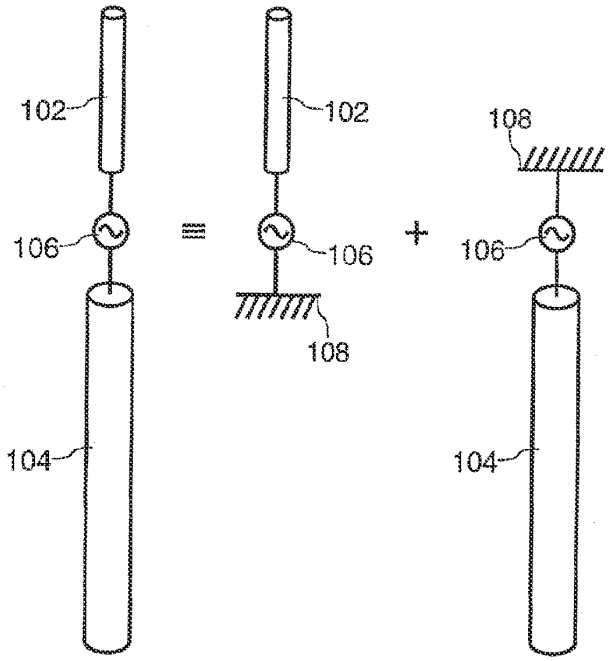


FIG.1

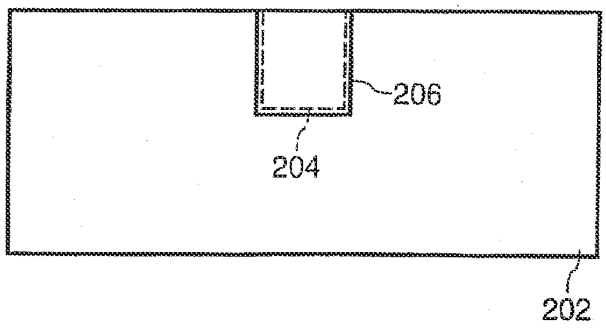


FIG.2

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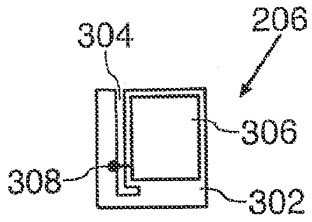


FIG.3

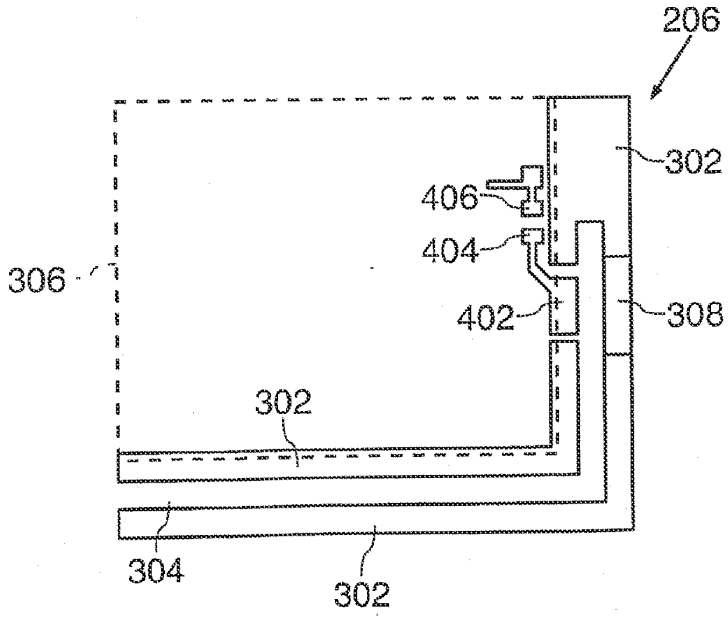


FIG.4

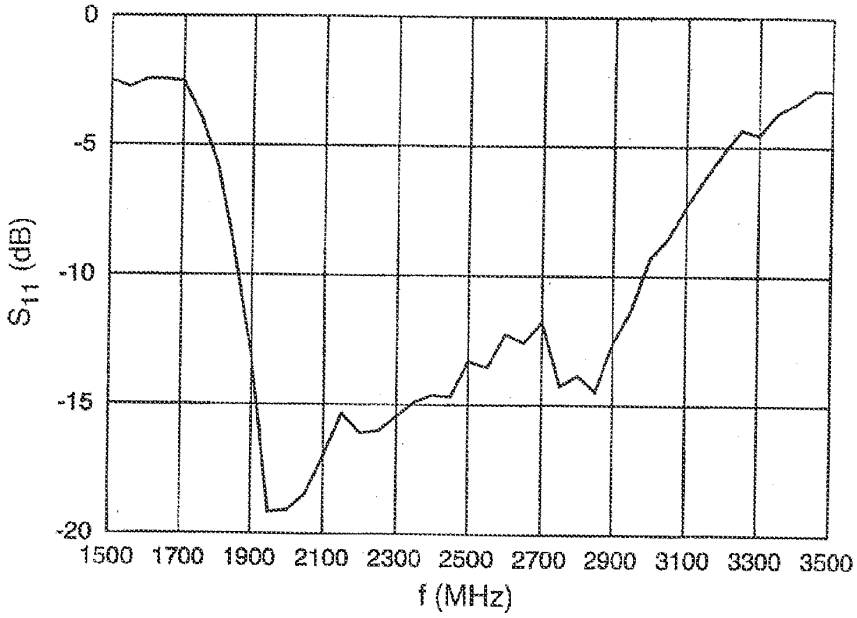


FIG.5

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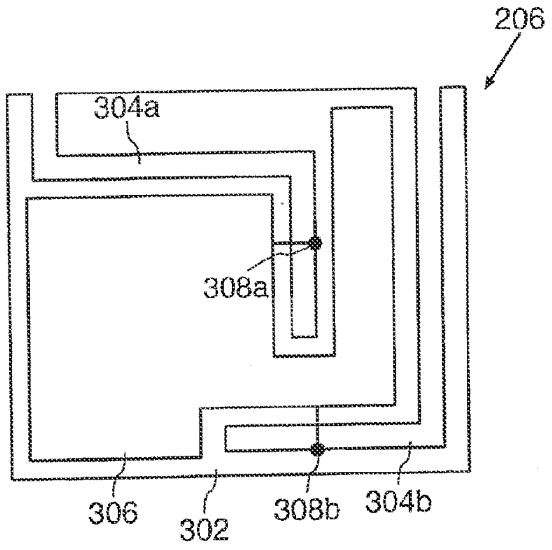

206
304a
308a
306
302
308b
304b

FIG.6

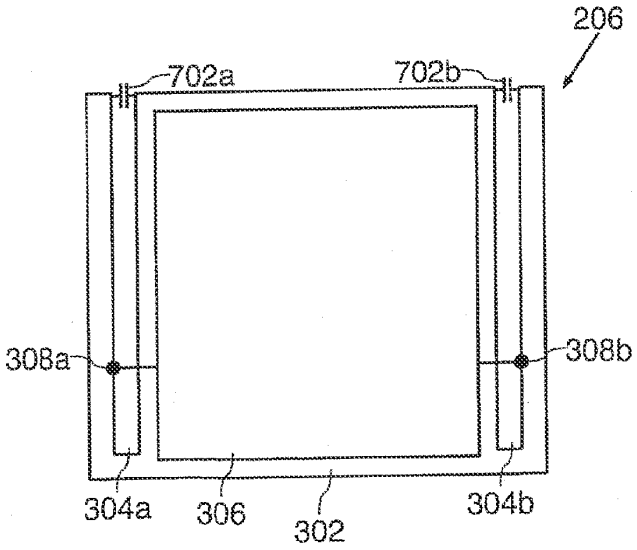

206
702a
702b
308a
308b
304a
306
302
304b

FIG.7

INTERNATIONAL SEARCH REPORT

Internat ication No
PCT/IB 03/01868

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q1/24 H01Q13/10 H01Q9/04 H01Q13/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 6 052 093 A (YAO NIAN JING ET AL) 18 April 2000 (2000-04-18) column 4, line 13 - line 63 column 5, line 14 - line 38 figures 1,2,6,7 abstract	1,6-9

-/--

[X] Further documents are listed in the continuation of box C. [X] Patent family members are listed in annex.

° Special categories of cited documents :

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 June 2003	23/06/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	von Walter, S-U

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INTERNATIONAL SEARCH REPORT

Internat lication No
PCT/IB 03/01868

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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X	US 6 031 503 A (DONALDSON STEPHEN R ET AL) 29 February 2000 (2000-02-29) column 3, line 11 -column 4, line 10 figures 2-4 abstract	1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Internal Application No
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Form PCT/ISA/210 (patent family annex) (July 1992)

BNSDOCID: <WO_____03096475A1_1_>

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
11 April 2002 (11.04.2002)

PCT

(10) International Publication Number
WO 02/29929 A2

(51) International Patent Classification⁷: H01Q 21/28, 21/30, 7/00, 9/28, 1/22, G06K 19/077

(21) International Application Number: PCT/GB01/04399

(22) International Filing Date: 3 October 2001 (03.10.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/678,630 3 October 2000 (03.10.2000) US

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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WO 02/29929 A2

(54) Title: MULTI-BAND WIRELESS COMMUNICATION DEVICE

(57) Abstract: The present invention relates to a wireless communication device, such as a transponder, that has a plurality of antennas for multi-frequency usage. The wireless communication device comprises a control system, communication electronics, memory and the aforementioned antennas. A wireless communication device having a pole antenna may be used with one or more loop conductor antennas to achieve the desired operating frequencies. A wireless communication device having a dipole antenna may be coupled across a loop conductor antenna to provide different loop conductor configurations depending on the frequency.

Multi-band Wireless Communication Device

The present invention relates to a wireless communication device and communication of information concerning an item containing the wireless communication device, and particularly to a wireless communication device supporting multi-frequency usage.

It is often desired to track and identify items, such as packages, containers, and the like, and to communicate information concerning such items wirelessly. One method of tracking and providing information concerning packages is to attach a wireless communication device, such as a radio frequency identification (RFID) transponder or other identification device, to packages or items. The information communicated concerning the packages or items may include expiration dates, "born on" dates, lot numbers, manufacturing information, and the like. A wireless communication device may be attached to an individual package, to a container containing multiple packages, or other item as the situation merits.

Different countries have allocated different portions of the electromagnetic spectrum for use with such wireless communication devices. For example, some countries may use frequency bands centered on 2.45 GHz and others may use bands centered on 13.56 MHz, 868 MHz, or 915 MHz. It is desirable to be able to communicate at a plurality of these frequencies to increase the functionality and utility of the wireless communication device. For each of these frequencies, the wireless communication device may need a different antenna. Multiple antennas inherently take up space in the wireless communication device that is considered valuable in this era of miniaturization. This situation is compounded when the needed electrical length for antennas operating at these different frequencies is taken into account.

The present invention relates to a wireless communication device, such as a transponder, that has a plurality of antennas for operation at multiple frequencies. The wireless communication device comprises a control system, communication electronics, memory, and the aforementioned antennas.

In a first embodiment, a dipole antenna is positioned across one or more nested loop conductor antennas to achieve multiple operating frequencies. Two conductive tabs are coupled to the wireless communication device to provide the dipole antenna. This dipole antenna provides a first operating frequency to the wireless communication device. The conductive tabs are also coupled across the nested loop conductor antenna through capacitive coupling. A second wireless communication circuit is also coupled to the nested loop conductor antenna. As the frequency increases, the conductive tabs across the nested loop conductor antenna become closer to a short. Therefore, different loop conductor antenna configurations in the nested loop conductor antenna resonate depending upon the frequency to provide multiple operating frequencies to the wireless communication device.

In a second embodiment, a pole antenna is coupled to the wireless communication device that serves as one antenna for a first operating frequency. At least one additional loop conductor antenna is placed in proximity to the pole antenna to provide at least one additional operating frequency.

The pole antenna may be a dipole antenna that is comprised of two conductive tabs coupled to the wireless communication device. Two loop conductor antennas are placed in close proximity to the tabs for capacitive coupling. Each of the loop conductor antennas resonate at their own design frequency. Since the tabs that serve as a dipole antenna are also coupled to the loop conductor antennas, the wireless

communication device is capable of operating at three frequencies. The first operating frequency is achieved through the dipole antenna. The second operating frequency is achieved through capacitive coupling between the wireless communication device and one of the loop conductor antennas. The third frequency is achieved through capacitive coupling between the wireless communication device and the other loop conductor antenna.

The above embodiment is also applicable to a monopole antenna arrangement whereby one conductive tab is coupled to the wireless communication device. A ground plane is additionally provided and coupled to the wireless communication device.

Variations on the second embodiment comprise using an asymmetrical dipole antenna that is coupled to loops of differing shapes and sizes. Likewise, manipulating the ground plane may also provide desired variations. In a first variation, an asymmetrical dipole antenna is coupled to differently sized loop antennas and a ground plane positioned underneath the dipole antenna. In another variation, the ground plane is slotted to minimize interaction between the loop antennas. In another variation, one of the loops includes a nested loop. In still another variation, the loop comprises a low frequency loop antenna.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 illustrates a schematic diagram of a wireless communication device and an interrogation reader;

Figure 2 illustrates a wireless communication device attached to an automobile;

Figure 3 illustrates a prior art antenna arrangement for a wireless communication device;

Figure 4 illustrates a first embodiment of an antenna arrangement for a wireless communication device;

Figures 5A-5F illustrate a number of different effective antennas in the embodiment of Figure 4;

Figure 6 illustrates a second embodiment of an antenna arrangement for a wireless communication device;

Figure 7 illustrates a first variation of the second embodiment of Figure 6;

Figure 8 illustrates a second variation of the second embodiment of Figure 6;

Figure 9 illustrates a third variation of the second embodiment of Figure 6;

Figure 10 illustrates a fourth variation of the second embodiment of Figure 6;

Figure 11 illustrates a fifth variation of the second embodiment of Figure 6;

Figure 12 illustrates a schematic diagram of a tracking and information system;

Figure 13 illustrates a schematic diagram of a synchronization device for dual chip wireless communication devices; and

Figure 14 illustrates a flow chart for the synchronization of data for dual chip wireless communication devices.

The present invention is directed to providing multi-frequency functionality for a wireless communication device, such as a transponder. Referring now to the drawings in general, and to Figure 1 in particular, it will be understood that the illustrations are for the purpose of describing specific embodiments of the present invention and are not intended to limit the invention thereto. A wireless communication device 130 is connected or attached to a device or article of manufacture or other material to

communicate information electronically and wirelessly concerning the device, article of manufacture, or other material.

One embodiment of the present invention uses a specific type of wireless communication device 130 called a radio frequency transponder. Herein, "transponder" is used interchangeably with "wireless communication device" 130; however, the present invention is not limited to using a transponder as the wireless communication device 130. Some wireless communications devices 130, such as that described in U.S. Patent No. 5,585,953, entitled "IR/RF radio transceiver and method", have both transmit and receive capability and can be used in the present invention. Other wireless communication devices 130 have receive capability and use the energy received to communicate back, such as described in U.S. Patent No. 6,078,259 entitled "Radio frequency identification tag". Such passive devices may likewise be used with the present invention. The wireless communication device 130 in the present invention can be any type of device that allows reception of wireless, electronic communications and is able to communicate in response thereto.

The transponder 130 may be made out of plastic or other suitable material and comprises a control system 134, wireless communication electronics 132, antenna assembly 136, and memory 138.

The wireless communication electronics 132 receive information wirelessly through at least one of the antennas in antenna assembly 136. The wireless communication electronics 132 assimilate the received information and communicate it to the control system 134. The control system 134 receives this information and controls the operation of the transponder 130. In one embodiment, the control system 134 is an integrated circuit or other type of microprocessor or micro-controller

electronics that controls the operations of the transponder 130. The control system 134 is connected to the wireless communication electronics 132 to communicate and receive transmissions.

The transponder 130 may also contain a magnet 142 to aid in the transponder's 130 attachment to the magnetic surface portion of an article if so desired. The magnetic surface portion may be a conductive material or may be a non-conductive material. The transponder 130 may also contain its own power source 140, such as a battery or reservoir capacitor, for needed power to carry out operations within the transponder 130 that are discussed later. U.S. Patent No. 4,857,893, entitled "Single chip transponder device", discusses a transponder having its own battery as a power source for a variety of functions. In this '893 Patent, the battery allows the transponder to be converted into a self-powered beacon device that periodically transmits its identifying encoded data word without the need for the presence of a carrier signal.

Figure 1 also depicts how communication is achieved with the transponder 130. An interrogation reader 100 contains interrogation communication electronics 102 and an interrogation antenna 104. Interrogation readers 100 are also referred to herein as interrogators. As used herein, the term "interrogator" refers to a wireless communications device capable of establishing communications with a plurality of corresponding wireless communication devices, herein referred to as "transponders," for the purpose of discriminating among and identifying individual transponders, e.g., by receiving and decoding an identification code. The interrogation reader 100 communicates to the transponder 130 by emitting a signal or command modulated in a signal 106 through the interrogation antenna 104. The interrogation antenna 104 may be any type of antenna that can radiate the modulated signal 106 through a field 108 so

that a compatible device such as a transponder 130 can receive such signal 106 through antenna assembly 136. The field 108 could be any of a variety of different types used in the communication industry including electric, magnetic, or electro-magnetic. The signal 106 is a message containing information and/or specific instructions for the transponder 130. The range of interrogation reader 100 is designed and configured so as to encompass the area in the immediate vicinity of interrogation reader 100.

When the transponder antenna assembly 136 is in the presence of the field 108 emitted by the interrogation antenna 104, the wireless communication electronics 132 are energized, thereby energizing the transponder 130. The transponder 130 remains energized so long as its antenna 136 is in the field 108 of the interrogation reader 100. The wireless communication electronics 132 demodulate the signal 106 and send a message containing information and/or specific instructions to the control system 134 for appropriate actions. For example, the request in the message may be for the transponder 130 to send back information stored in memory 138 about the article to which the transponder 130 is attached, including, but not necessarily limited to: its date of manufacture, place of manufacture, "born-on" date, expiration date, tracking information, status information, type of article, temperature of the article or its surroundings (if a temperature sensor is provided) or other distinguishing characteristics of the article. The transponder 130 communicates information to the interrogation reader 100 by altering the contents of the signal 106 in its return path to the interrogation reader 100.

Alternative forms exist for communicating with a wireless communication device 130. For instance, the wireless communication device 130 may have a transmitter so that it can send information to a remote source without having to use the

signal 106 return as a means for communication. The wireless communication device 130 may contain its own power source 140 if it transmits information separately from its reception. It is understood to one of ordinary skill in the art that there are many other manners to provide a wireless communication device 130 to communicate wirelessly for use with the present invention, such as a transponder 130, and that the present invention includes but is not limited to the particular manners described above.

Figure 2 illustrates a particular embodiment of the transponder 130 attached to a particular article or article of manufacture, namely, an automobile 160. The transponder 130 is mounted to a magnetic surface portion 162 of the automobile 160 using magnetic force for attraction. Magnet 142 associated with the transponder 130 may be used to provide an attractive force, causing the wireless communication device 130 to attract to and attach to the magnetic surface portion 162 of the automobile 160. Magnet 142 may be a permanent magnet or electro-magnet. Magnet 142 may be provided by constructing the transponder 130 and/or its elements, such as antenna assembly 136, out of magnetic material. Such embodiments are disclosed in commonly owned, co-pending U.S. Patent application entitled "Wireless communication device attachment and detachment device and method", Serial No. US-09/618,506, filed 18 July 2000. The transponder 130 may also be attached to an article using a fastener or an adhesive material between the transponder 130 and the article.

Through any appropriate attachment techniques, such as those described above, the transponder 130 may be attached to articles for tracking or information purposes. For instance, the location of the automobile 160 may be tracked through use of the transponder 130 if the transponder 130 contains an identification means, such as a number, relating to the particular automobile 160 to which the transponder 130 is

attached. Additional information concerning the automobile 160, including its make, model, etc., can be communicated and/or tracked wirelessly. Other devices or items may be tracked instead of an automobile 160. For example, packages or containers may be tracked as described in commonly owned U.S. Patent Application Serial No. 09/618,505, entitled Wireless Communication Device and Method, filed 18 July 2000. Examples include chip bags, chewing gum packages, beer kegs, and the like.

A presently existing wireless communication device is illustrated in Figure 3. In particular, the wireless communication device 200 conforms to an international standard, ISO-15693-2. Wireless communication device 200 operates at 13.56 MHz by using magnetic field coupling, involving the use of tuned coils 202 as a loop conductor antenna 204 on a first side of a substrate 206. Typically, an integrated chip 208 is mounted on the opposite side of the substrate 206. Electrical connections extend from the integrated chip 208, through the substrate 206 to provide an electrical connection between the wireless communication electronics 132 (Fig. 1) and the antenna 204.

Note that while this is an example of a prior art device, other prior art devices also exist which operate at another standard for 125 kHz. The present invention is also adapted for use with such devices.

As alluded to above, different interrogation readers 100 may interrogate a wireless communication device 130 at different frequencies. To that end, it may be necessary to add antennas to the wireless communication device 130. One embodiment is illustrated in Figure 4. Wireless communication device 130 is substantially similar to wireless communication device 200. However, in addition to the loop antenna 204, a dipole antenna 250 is placed across the coils 202. Dipole antenna 250 comprises a first tab 252, a second tab 254, each of which may be approximately a quarter wavelength

long relative to a desired operating frequency, and an integrated circuit 256. The tabs 252, 254 are constructed out any type of material desired so long as the material is conductive. Such material be a ferrous material, including metal, steel, iron, or the material may be aluminum or other type of conducting material. In another embodiment, a conductor made from metal loaded ink may be used as described in U.S. Patent 5,566,441, entitled "Attaching an electronic circuit to a substrate". In particular, a multi-layer screen or other printing method may be used to create the entire tag while the chips, 208, 256 are inserted in the ink whilst still wet. As used herein, the terms chips and circuits are used interchangeably.

In one implementation, the dipole antenna 250 is operative at 2.45 GHz. The integrated chip 256 may contain the wireless communication electronics 132, control system 134 and other desired components. An example of an appropriate integrated circuit comprises those used by INTERMEC in the Intellitag(r) labels and those used by SCS in the DL100 label. Note that the loops 202 act to load capacitively the tips of the dipole antenna 250. While not shown explicitly, a dielectric material may be placed between the tabs 252, 254 and the coils 202 to preclude the creation of an outright short thereacross. An effective short at higher frequencies (i.e., above the operative frequency of the loop antenna 204) is permissible.

This arrangement creates a plurality of effective antennas that may be used with an interrogation reader 100. Figures 5A-5F illustrate a number of different effective antennas that are present within the wireless communication device 130 of Figure 4. The arrows within the loops of Figures 5A-5F illustrate the effective loop. Figure 5A illustrates the effective antenna formed by the dipole antenna 250. Even coupled to the wireless communication device 130, the dipole antenna 250 still operates at its desired

frequency, which, in an exemplary embodiment, is 2.45 GHz. Figure 5B illustrates the loop conductor antenna 204, which, likewise operates at its desired frequency, which, in an exemplary embodiment is 13.56 MHz. Figure 5C illustrates a first created loop conductor antenna 260 that enables reception in a third band. In particular, the capacitance between the tip of the tabs 252, 254 and the coils 202 effectively shorts the coils 202 together at higher frequencies, treating them as a single conductor. This coupling links the integrated chip 256 to two additional loops formed by the intersection of loop 204 with the dipole antenna 250. A first created loop antenna 260 is formed by the top half of the loop 204, the tabs 252, 254 of the dipole antenna 250, and the integrated chip 256. In an exemplary embodiment, this may operate at 915 MHz.

As illustrated in Figure 5D, a second created loop antenna 262 is formed by the lower half of the loop 204, the tabs 252, 254 of the dipole antenna 250, and the integrated chips 208, 256. If the UHF capacitance of the integrated chip 208 is correctly selected, it is possible to tune the second loop 262 to a different UHF frequency from the first loop 260, such as the desirable 868 MHz.

It should be appreciated that both the first and second loops 260, 262 can be made to act as UHF antennas by ensuring that the net inductance of these loops at the UHF frequency, the impedance of the chip 256 (and chip 208 in loop 260), and the series capacitances formed by the parallel plate coupling of the tab 252, 254 tips to the coils 202 collectively resonate at the desired frequencies. This can be controlled by varying the size of the tabs 252, 254 and the position of the dipole antenna 250 on the wireless communication device 130. In one embodiment, the transponder 130 operates at a 0.5 meter range at 13.56 MHz, 3 meters at 915 MHz, and 0.5 meters at 2.45 GHz.

The tabs 252, 254 capacitively couple to the coils 202, and create an effective short thereacross at UHF frequencies. It may also be possible that the tabs 252, 254 may be used as feed lines that capactively couple to the coils 202 and drive the same at still other frequencies. Since the coils are effectively shorted at some frequencies, but not at others, a loop 264 (Fig. 5E) may be generated and used as a loop conductor antenna. Likewise, at other frequencies, the integrated chip 208 may still be part of the electrical length of a loop 266 (Fig. 5F), allowing yet another operative frequency.

It may also be possible to vary how the coils are capacitively shorted together by the tabs 252, 254, by varying the size and shape of the tabs 252, 254. For example, flaring or tapering the tabs 252, 254 may make it more likely that only a portion of the coils are shorted together at certain frequencies. This allows still other frequencies to be used as needed or desired.

Note that, for the purposes of the present invention, this wireless communication device 130 has two or more loop conductor antennas, they just happen to share at least portions of the same conductor coil.

For wireless communication devices 130 that contain two chips 208, 256 coupled to common antennas, there may be a desire to synchronize the data carried in each chip 208, 256, so that when they are interrogated at any of the operational frequencies, the same data is returned. A simple method of achieving this desired result is a dual reader/writer device 700, as illustrated in Figure 13. Dual reader/writer device 700 comprises a controller 702 controlling two or more interrogation readers 100 by data flow connections 704. Dual reader/writer device 700 may include an optional communicative link 706 to a remote source. Wireless communication device 130 is

brought into the communicative fields of the at least two interrogation readers 100 and data exchanged therebetween.

It may be advantageous to have all the data written to memory 138 of the wireless communication device 130 to be time and date stamped. In use, information may be read and written by the interrogation readers 100 operating at only a single frequency, allowing memory 138 on the different chips 208, 256 to be modified in different manners at different times by different readers. This creates different outputs from the different chips 208, 256. Understandably, this situation is undesirable.

The methodology is illustrated as a flow chart in Figure 14. One of the interrogation readers 100 reads the data from the first chip (for example, chip 208) (block 800). The second interrogation reader 100 reads the data from the second chip (for example, chip 256) (block 802). The controller 702 compares the data returned from the two chips 208, 256 (block 804). If the data is synchronous, no action is required and the process ends (block 806). If however the data is not synchronous, the controller 702 may archive all the data from both chips 208, 256 (block 808). The controller 702 may then instruct the appropriate interrogation reader 100 to write the data from the chip 208, 256 with the newest date stamp to the chip 208, 256 carrying the older date stamp (block 810). The data is now synchronous between the two chips 208, 256 and the process ends (block 812). Other techniques of synchronization are also possible.

A second embodiment of a multi-band wireless communication device is illustrated in Figure 6. In particular, the wireless communication device 130 comprises a dipole antenna 250 and a pair of loop conductor antennas 302, 304 oppositely positioned from one another on either side of the dipole antenna 250. Dipole antenna

250 comprises a first tab 252, a second tab 254, and an integrated chip 256 as previously described and may be operative at 2.45 GHz. Loop conductor antennas 302, 304 may comprise multiple coils (not shown) or a single coil of microstrip and may be sized as needed to achieve a desired operating frequency. Note that the gaps 306 between the tabs 252, 254 and the loop conductor antennas act as series capacitors, forming resonant circuits between the integrated chip 256 and the two loop conductor antennas 302, 304. In one version of this embodiment, the loop conductor antennas 302, 304 operate at 868 MHz and 915 MHz, respectively. An alternate way to tune the loop conductor antennas 302, 304 is to move the relative placement of the dipole antenna 250. If the dipole antenna 250 were closer to one loop (302 or 304) than the other, there would be an increased coupling capacitance between the dipole 250 and the closer loop (302 or 304), impacting the operating frequency. Likewise, there would be a lower coupling capacitance between the dipole and the farther loop (302 or 304), also impacting the operating frequency of that loop (302 or 304) as well. These antennas 250, 302, 304 may likewise be positioned on a substrate 206. In other versions of the present embodiment, the antennas 250, 302, 304 may be positioned on different sides of the substrate 206. Variations in which side of the substrate 206 on which the antennas are placed, the thickness of the substrate, and the like may also be used to tune the antennas 250, 302, 304 to the desired frequencies. Likewise, variations in the dimensions of the loop, the number of coils, and even the material used may impact the operating frequencies of the loops.

Also note that one tab 252, 254 may be used with this embodiment to create a monopole-type antenna if a ground plane (not shown) is provided that is coupled to transponder 130. Likewise, only one loop conductor antenna 302, 304 may be used to

create a device that operates at two different frequencies; one through the pole-type antenna and the other through the loop conductor antenna 302, 304.

A number of the variations just discussed, as well as some others are presented in Figures 7-11. In Figures 7-11, the coils are illustrated as microstrip antennas. Other arrangements are possible. Specifically, Figure 7 illustrates a transponder 400 comprising an asymmetrical dipole antenna 402 coupled to a pair of asymmetrical loop antennas 410, 412. As illustrated in Figure 7, the dipole antenna 402 is positioned such that loop antenna 410 is smaller than loop antenna 412. Dipole antenna 402 comprises asymmetrical tabs 404, 406 as illustrated. Variations in the nature of the asymmetry to achieve the desired operating frequencies are considered within the skill of those in the industry. A further discussion of asymmetrical dipole antennas may be found in commonly owned U.S. patent application Serial No. 09/678,271, entitled Wireless Communication Device and Method. A ground plane 408 is further used to tune the antennas 402, 410, 412. Chip 414 controls all the antennas 402, 410, 412. Further tuning may be achieved by varying the position of the various elements on the substrate 206. For example, some elements may be on one side, some embedded, and some on the other side; all the elements may be embedded; all the elements on one side; or other arrangement as needed or desired. It should be appreciated that the ground plane 408 may be isolated from the other elements to provide the desired grounding effect, but such may be done with a dielectric tape or the like as is well understood. Again, this wireless communication device 400 has multi-frequency functionality in that the dipole antenna 402 may operate at a first frequency, the first loop antenna 410 may operate at a second frequency, and the second loop antenna 412 may operate at a third frequency.

Figure 8 illustrates a second variant wireless communication device 400A, wherein the ground plane 408A is slotted behind the dipole 402 to minimize interaction between the loop antennas 410, 412. This is a function of the fact that at UHF frequencies, the gap will appear as a high impedance gap. At the microwave frequencies of the dipole 402, the gap has a relatively low impedance and looks like a continuous ground plane, allowing the dipole 402 to operate normally.

Figure 9 illustrates a third variant with nested loops for improved bandwidth response. In particular, wireless communication device 450 comprises an asymmetrical dipole antenna 402, a ground plane 408, a first loop 412, a second loop 452, and a chip 414. Second loop 452 comprises a first part 454 and a second part 456, which are nested and coupled to the dipole 402. If the loops are similarly sized, but not identical, the overall circuit behaves like two coupled tuned circuits, giving an overall wider receive bandwidth than would be achieved with one loop.

Figure 10 illustrates a fourth variant wireless communication device 500. Wireless communication device 500 comprises a dipole antenna 402, a ground plane 408, a first loop antenna 412, and a second loop antenna 502. Second loop antenna 502 is electrically longer at low frequencies such as 13.56 MHz. Additionally, it should be noted that the coils of the second loop antenna 502 may be separated by a dielectric tape, or even by having an opposite surface connection.

Figure 11 illustrates a fifth variant wireless communication device 550. Wireless communication device 550 comprises a dipole antenna 402, a slotted ground plane 408B, a first loop antenna 412, and a second loop antenna 502A. The first loop antenna 412 is operative at UHF frequencies, the dipole antenna 402 at microwave frequencies, and the second loop antenna 502A is operative at low frequencies akin to

second loop antenna 502. The second loop antenna 502A is coupled to the chip 414 via capacitance between the two plates 552, 554 of the slotted ground plane 408B. In this variant, a thin substrate 206 allows increases in the capacitive coupling between the dipole antenna 402 and the second loop antenna 502A. The narrow gap in the ground plane 408B is seen as a relatively low impedance gap at microwave frequencies, allowing the dipole antenna 402 to function normally.

The variants and embodiments of Figures 6-11 are designed more from a fresh perspective than with an eye towards retrofitting. That does not mean that these variations may not be used in a retrofit context, but the presently commercially available wireless communication devices 200 are not designed to accommodate these variations as easily. To that end, the embodiments of Figures 6-11 are designed to operate with a single RFID chip, 256 or 414. Chip 256 or 414 can sense in a simple way which frequency at which the interrogation is occurring. If the chip 256, 414 has an input port connected to the antenna terminals prior to the internal rectifier, it will 'see' 13.56 MHz when being interrogated at this frequency, but not when being interrogated at higher frequencies. This is useful because when operating at 13.56 MHz, the standard requires that the chip 256, 414 clock off the received field. This may also be helpful because the chip 256, 414 may change modulation methods, data rates or the like depending on the received frequency. Alternatively, the interrogator 100 may simply send an identifier as part of the interrogation message. The identifier may identify the frequency at which the interrogator 100 is operating. This identifier may be in the form of amplitude modulation of the signal or other technique as desired.

Figure 12 illustrates one type of tracking system whereby the transponder 130 attached to articles 161, for example, automobile 160, can be tracked through an

environment such as a factory, distribution facility or storage facility. For example, the transponder 130 connected to article 161 passes a first interrogation point 150 that includes an interrogation reader 100. When the article 161 and its attached transponder 130 are in the presence of the interrogation reader 100 as described previously, a message containing information and/or a specific request for information may be transmitted by the interrogation reader 100 and received by the transponder 130. This process continues as the article 161 moves to a second interrogation point 152, a third interrogation point 154, a fourth interrogation point 156, and on to a last interrogation point 158.

A central control system 159 maintains the information from interrogation readers 100 and monitors the movement of the articles 161 through the facility. The information received by each of the interrogation readers 100 may be forwarded to the central control system 159 in a variety of architectures such as parallel or serial communication or through use of a local area network (LAN) or wide area network (WAN). Such architecture may include wiring between the interrogation readers 100 and the central control system 159 or may be wireless communication. The central control system 159 may also send information to the interrogation reader 100 to be transmitted back to the transponder 130 attached to the article 161 for a variety of purposes, including for identification. If the central control system 159 is designed to have knowledge of anticipated or expected whereabouts of the articles 161, then an alarm may be generated if the control system 159 expects to receive information about a particular article 161 and does not. Other situation based alarms may also be possible, such as when an item appears at the same station twice or if some other unexpected situation occurs.

Note that wireless communication devices 130 having their own transmission capability may still be used for tracking and communicating information concerning articles 161 without the use of interrogation readers 100. In its simplest form, a receiver to receive communication from the wireless communication device 130 would be needed. Alternatively, multiple receivers may be used to triangulate the position of the tracked article 161. If the system tracks and/or receives information from more than one wireless communication device 130, the system may need to have the ability to receive and transmit on different frequencies in order to distinguish wireless communication devices 130. However, an identification stored in memory 138 of the transponder 130 may also be used to distinguish wireless communication devices 130. During commissioning of each transponder 130, it may be necessary to place the transponder 130 in range of an interrogation reader 100 to erase previously stored information in memory 138 or to store particular data or configuration information about the article 161 in memory 138 for later use.

It should be appreciated that while the present invention is phrased as being operative at certain frequencies, the intended interpretation of such comments is that some bandwidth centered about the operative frequencies is used. Thus, for example, stating that the dipole antenna 250 may be operative at 2.45 GHz is intended to mean that the dipole antenna 250 operates on a channel having a bandwidth centered at 2.45 GHz. This is true for the other operative frequencies as well.

Claims:

1. A wireless communication device comprising: communication electronics; a first loop conductor antenna operating at a first frequency, said first loop conductor antenna being operatively connected to said communication electronics; a second loop conductor antenna operating at a second frequency, said second loop conductor antenna being operatively connected to said communication electronics; and a pole antenna operating at a third frequency, said pole antenna being operatively connected to said communication electronics, said communication electronics selectively communicating with a remotely positioned interrogator through one of said antennas.

2. A wireless communication device according to claim 1, wherein said first loop conductor antenna operating at a first frequency comprises a first loop conductor antenna operating at 868 MHz.

3. A wireless communication device according to claim 1, wherein said first loop conductor antenna operating at a first frequency comprises a first loop conductor antenna operating at 13.56 MHz.

4. A wireless communication device according to claim 1, further comprising a third loop conductor antenna operating at a fourth frequency.

5. A wireless communication device according to claim 4, wherein said first loop conductor antenna, said second loop conductor antenna, and said third loop conductor antenna share a loop conductor.

6. A wireless communication device according to claim 5, wherein said first loop conductor antenna operates at 868 MHz, said second loop conductor antenna operates at 915 MHz, and said third loop conductor antenna operates at 13.56 MHz.

7. A wireless communication device according to claim 1, wherein said pole antenna operates at 2.45 GHz.

8. A wireless communication device according to claim 1, wherein said pole antenna comprises a dipole antenna and second communication electronics, said first communication electronics being associated with one of said loop conductor antennas and said second communication electronics being associated with said dipole antenna.

9. A wireless communication device according to claim 1, wherein said pole antenna is positioned between said first loop conductor antenna and said second loop conductor antenna and capacitively couples to said first and second loop conductor antennas.

10. A wireless communication device according to claim 1, wherein said pole antenna is positioned across said first and second loop conductor antennas.

11. A wireless communication device according to claim 1, wherein said pole antenna comprises at least one tab.

12. A wireless communication device according to claim 11, wherein said pole antenna further comprises a ground plane and said tab comprises a monopole antenna.

13. A wireless communication device according to claim 11, wherein said pole antenna comprises two tabs to form a dipole antenna.

14. A wireless communication system comprising: a first wireless communication device coupled to a loop conductor antenna operating at a first frequency; and a second wireless communication device coupled across said loop conductor antenna on one side of said first wireless communication device, said second wireless communication device coupling to said loop conductor antenna including said first wireless communication device at a second operating frequency and coupling to said loop

conductor antenna excluding said first wireless communication device at a third operating frequency.

15. A wireless communication system according to claim 14, further comprising an interrogator operating at one of said frequencies and interrogating one of said wireless communication devices.

16. A wireless communication system according to claim 14, further comprising an article to be tracked by one of said wireless communication devices, said article being attached to one of said wireless communication devices.

17. A wireless communication system according to claim 14, wherein said first wireless communication device operates at 13.56 MHz.

18. A wireless communication system according to claim 14, wherein said second wireless communication device operates at 868 MHz and 915 MHz.

19. A wireless communication system according to claim 14, wherein said second wireless communication device further comprises a dipole antenna operating at a fourth frequency.

20. A wireless communication system according to claim 19, wherein said dipole antenna operates at 2.45 GHz.

21. A method of tracking an item, comprising: interrogating a wireless communication device at a first frequency through a first loop conductor antenna on the wireless communication device; interrogating the wireless communication device at a second frequency through a dipole antenna on the wireless communication device; and interrogating the wireless communication device at a third frequency through a second loop conductor antenna on the wireless communication device.

22. A method according to claim 21, wherein interrogating the wireless communication device at a second frequency through a dipole antenna on the wireless communication device comprises interrogating the wireless communication device at a second frequency through a dipole antenna capacitively coupled to said first and second loop conductor antennas.

23. A method according to claim 21, wherein interrogating the wireless communication device at a second frequency through a dipole antenna on the wireless communication device comprises interrogating the wireless communication device at a second frequency through a dipole antenna positioned across said first and second loop conductor antennas.

24. A method according to claim 21, further comprising interrogating the wireless communication device at a fourth frequency through a third loop conductor antenna on the wireless communication device.

25. A method according to claim 21, further comprising communicating from an interrogator to a central control system.

26. A transponder comprising: a dipole antenna; a first loop conductor antenna; and a second loop conductor antenna, said first and second loop conductor antennas being positioned on opposite sides of said dipole antenna and capacitively coupled thereto.

27. A transponder according to claim 26, further comprising communication electronics communicatively coupled to said antennas.

28. A transponder according to claim 26, wherein said dipole antenna is adapted to operate at 2.45 MHz, said first loop conductor antenna is adapted to operate at 915 MHz, and said second loop conductor antenna is adapted to operate at 868 MHz.

29. A wireless communication device comprising: wireless communication electronics; an asymmetrical dipole antenna operatively connected to said wireless communication electronics, said dipole antenna being operative at a first frequency; and at least one loop antenna capactively coupled to said dipole antenna and operative at a second frequency.

30. A wireless communication device according to claim 29 further comprising a second loop antenna capacitively coupled to said dipole antenna and operative at a third frequency.

31. A wireless communication device according to claim 29 further comprising a ground plane operative with said dipole antenna.

32. A wireless communication device according to claim 31 wherein said ground plane is slotted.

33. A wireless communication device according to claim 29 wherein said dipole antenna is operative at a microwave frequency.

34. A wireless communication device according to claim 29 wherein said at least one loop antenna is operative at a low frequency.

35. A wireless communication device according to claim 34 further comprising a second loop antenna operative at a UHF frequency and capacitively coupled to said dipole antenna.

36. A wireless communication device according to claim 29 wherein said at least one loop antenna comprises a nested part to increase bandwidth reception on said at least one loop antenna.

37. A method of testing output from a wireless communication device comprising at least two sets of wireless communication electronics, said method comprising:

interrogating the wireless communication device at a first frequency to query one of said at least two sets of wireless communication electronics; interrogating the wireless communication device at a second frequency to query a second one of said at least two sets of wireless communication electronics; and comparing outputs received from said wireless communication device at said first and second frequencies.

38. A method according to claim 37 further comprising synchronizing said outputs.

39. A method according to claim 38 wherein synchronizing said outputs comprises sending instructions to one of said wireless communication electronics to update information stored in memory associated therewith.

40. A method according to claim 39 further comprising archiving both outputs.

41. A method according to claim 40 further comprising comparing date stamps associated with each of said outputs.

42. A method according to claim 41 wherein sending instructions to one of said wireless communication electronics to update information stored in memory associated therewith comprises sending the output having the later date stamp to the wireless communication electronics whose output comprises the earlier date stamp.

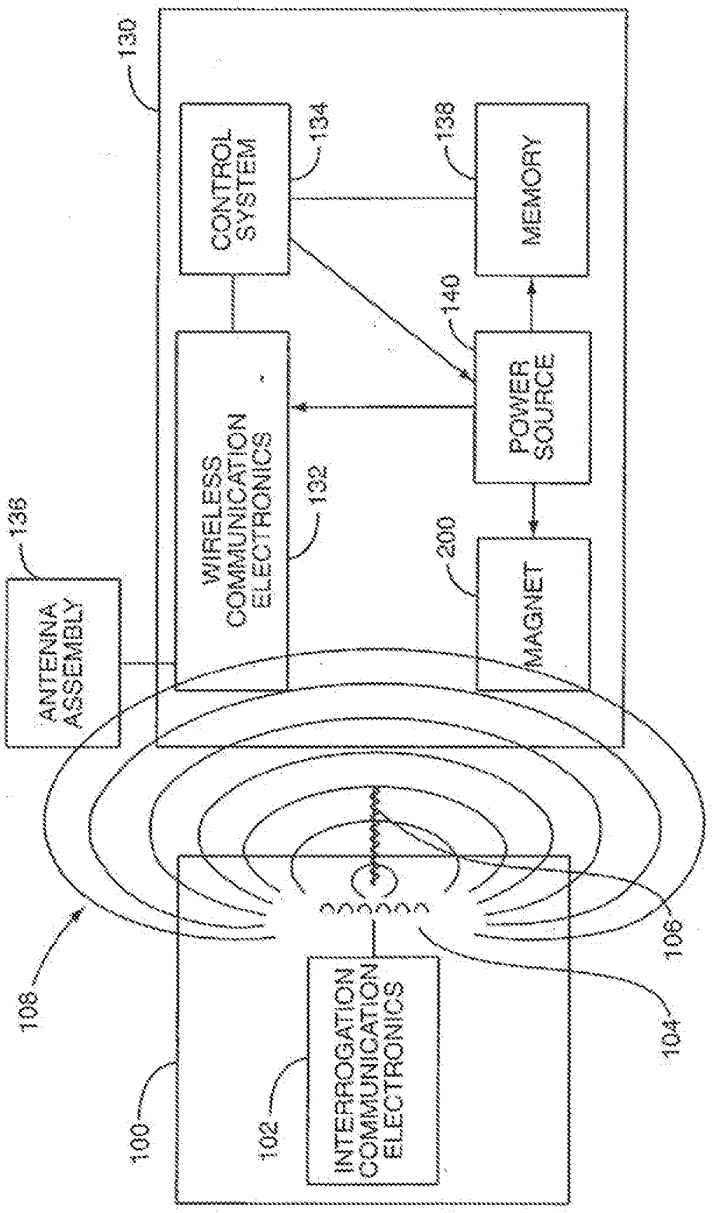

130
CONTROL SYSTEM
134
138
MEMORY
140
POWER SOURCE
WIRELESS COMMUNICATION ELECTRONICS
132
136
ANTENNA ASSEMBLY
200
MAGNET
108
106
104
100
102
INTERROGATION COMMUNICATION ELECTRONICS

FIG. 1

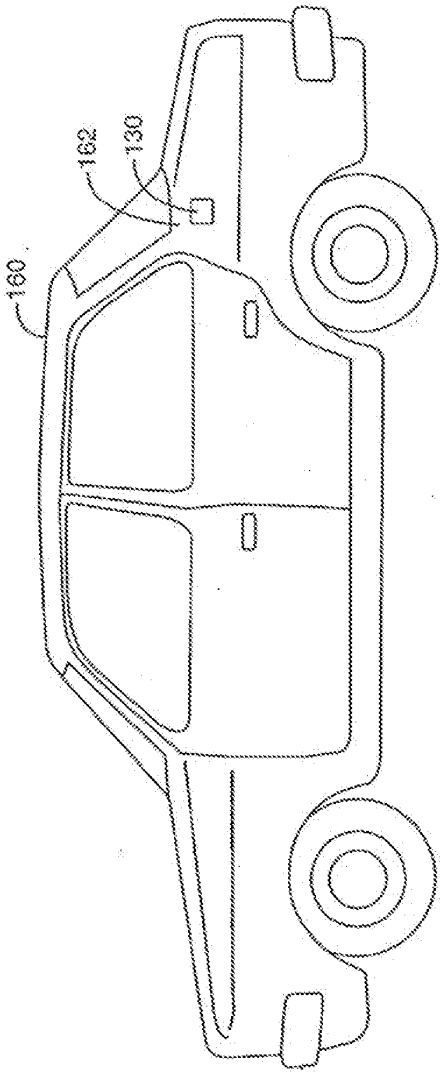


FIG. 2

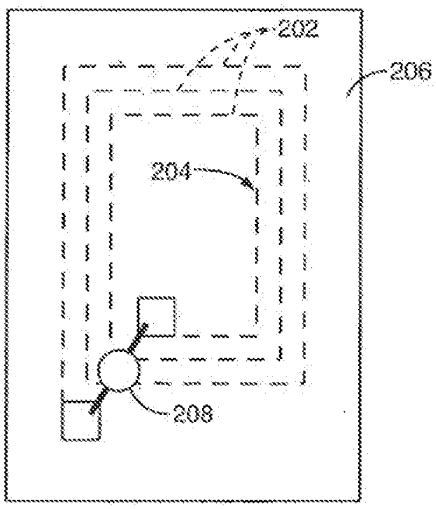


FIG. 3
PRIOR ART

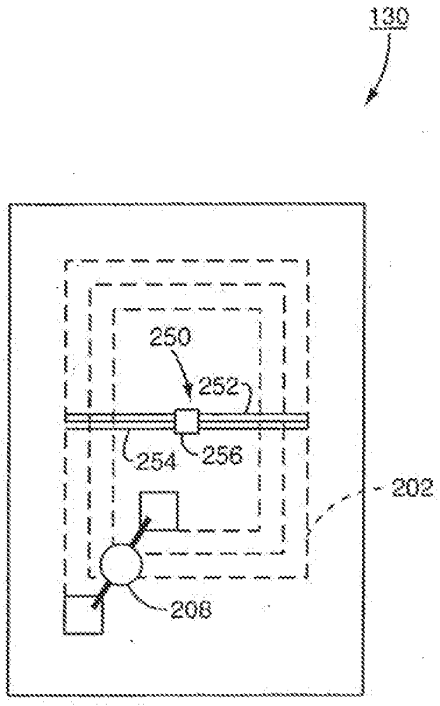


FIG. 4

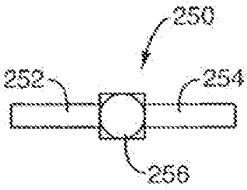


FIG. 5A

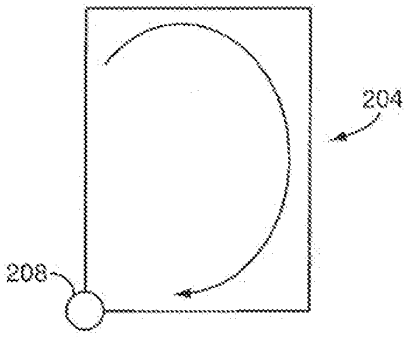


FIG. 5B

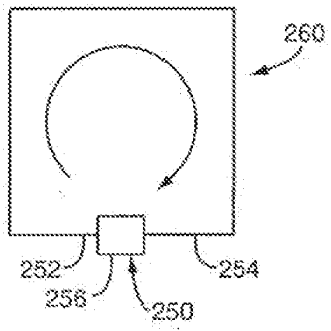


FIG. 5C

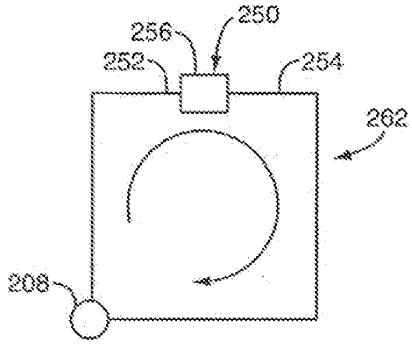


FIG. 5D

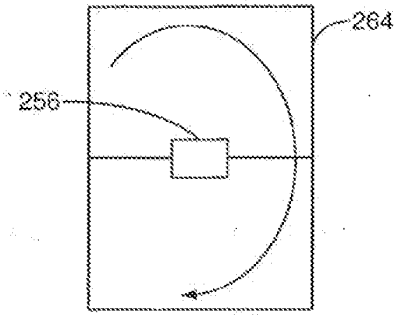


FIG. 5E

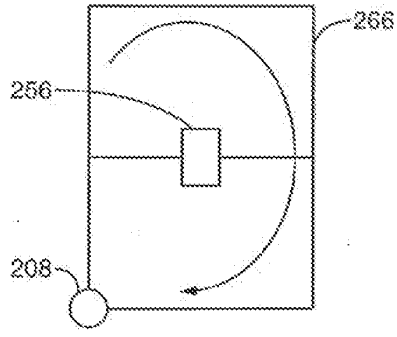


FIG. 5F

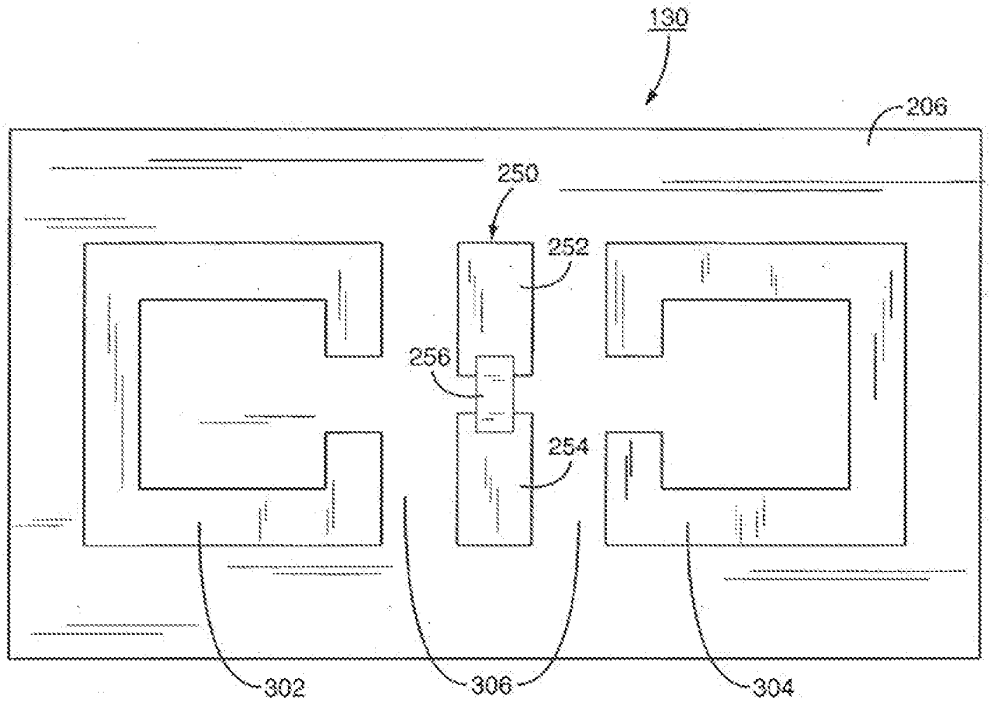


FIG. 6

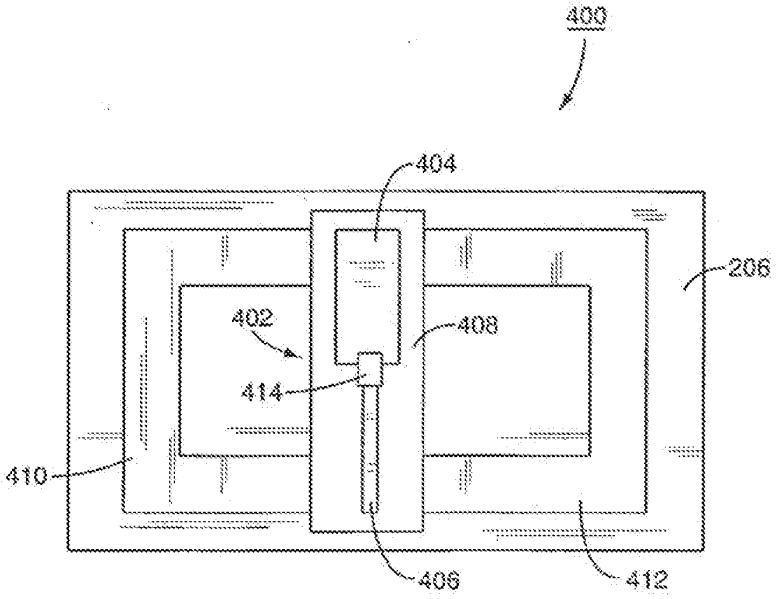


FIG. 7

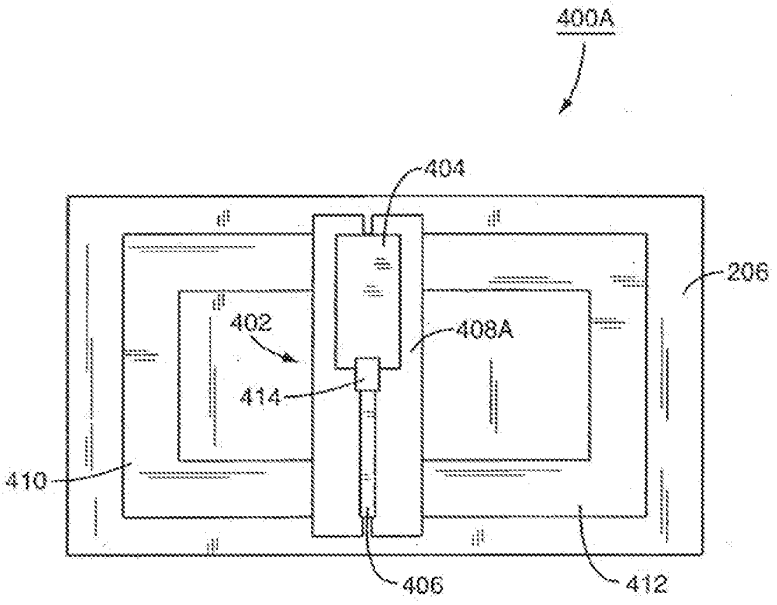


FIG. 8

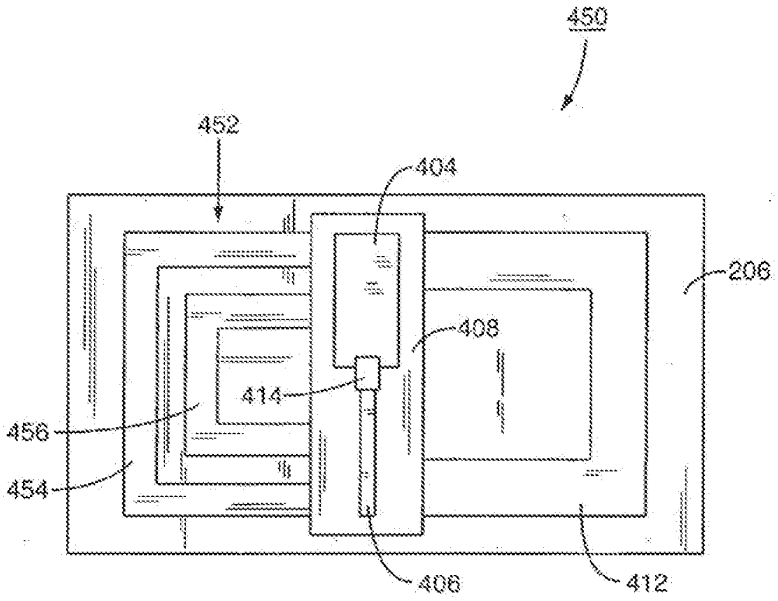


FIG. 9

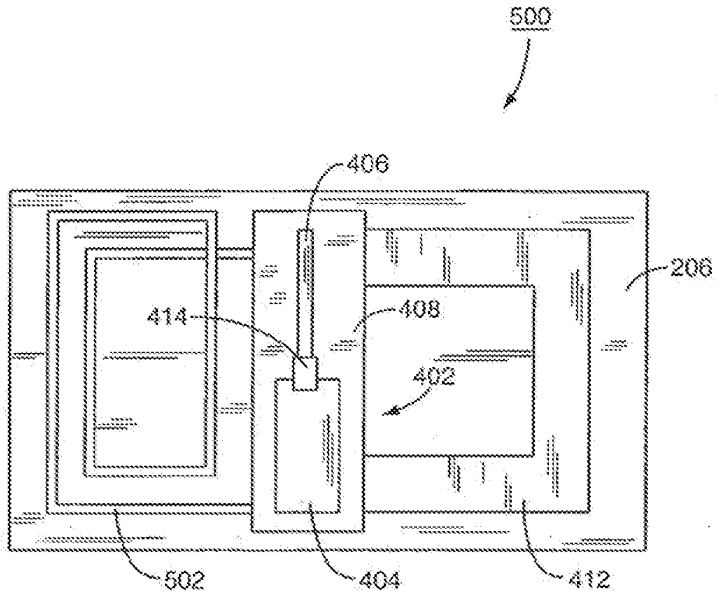


FIG. 10

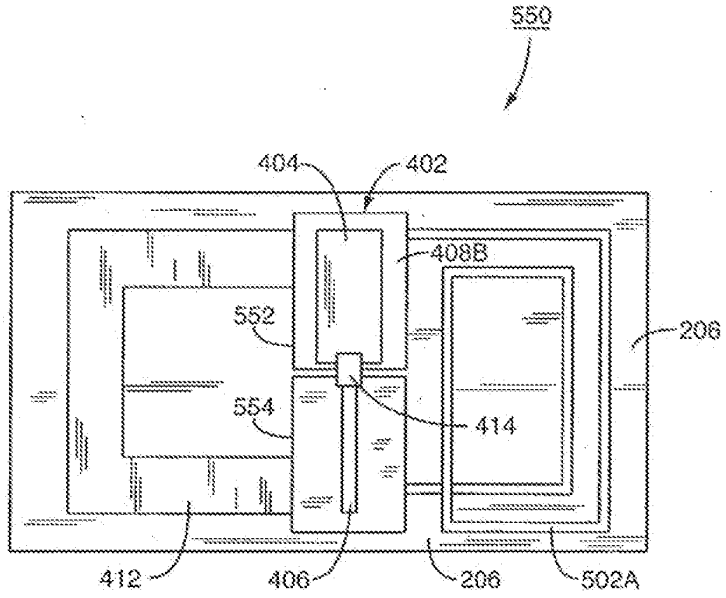


FIG. 11

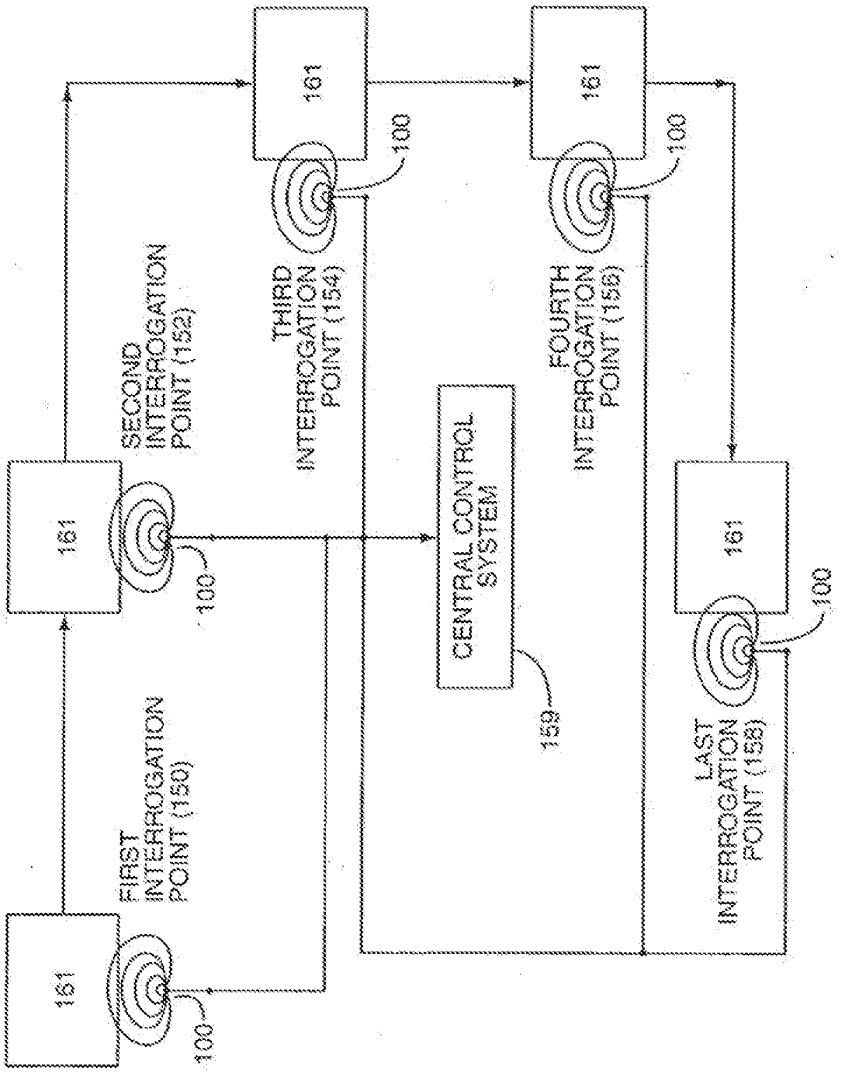

161
161
161
161
161
100
100
100
100
100
FIRST INTERROGATION POINT (150)
SECOND INTERROGATION POINT (152)
THIRD INTERROGATION POINT (154)
FOURTH INTERROGATION POINT (156)
LAST INTERROGATION POINT (158)
CENTRAL CONTROL SYSTEM
159

FIG. 12

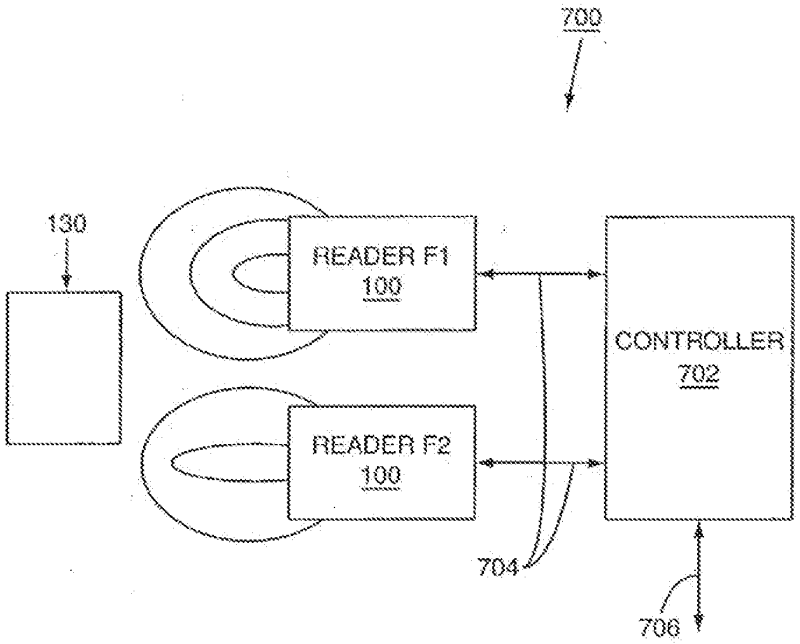


FIG. 13

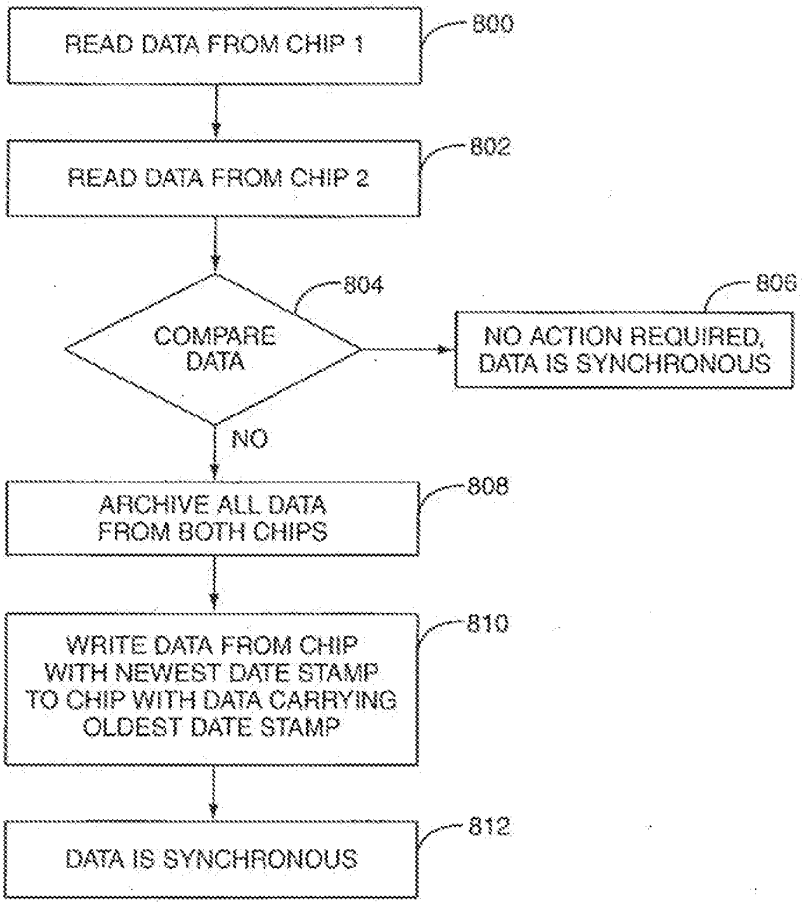

READ DATA FROM CHIP 1
800
READ DATA FROM CHIP 2
802
COMPARE DATA
804
NO ACTION REQUIRED, DATA IS SYNCHRONOUS
806
NO
ARCHIVE ALL DATA FROM BOTH CHIPS
808
WRITE DATA FROM CHIP WITH NEWEST DATE STAMP TO CHIP WITH DATA CARRYING OLDEST DATE STAMP
810
DATA IS SYNCHRONOUS
812

FIG. 14

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 July 2001 (26.07.2001)

PCT

(10) International Publication Number
WO 01/54225 A1

(51) International Patent Classification⁷: H01Q 1/36

(21) International Application Number: PCT/EP00/00311

(22) International Filing Date: 19 January 2000 (19.01.2000)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 01/54225 A1

(54) Title: SPACE-FILLING MINIATURE ANTENNAS

(57) Abstract: A novel geometry, the geometry of Space-Filling Curves (SFC) is defined in the present invention and it is used to shape a part of an antenna. By means of this novel technique, the size of the antenna can be reduced with respect to prior art, or alternatively, given a fixed size the antenna can operate at a lower frequency with respect to a conventional antenna of the same size.

SPACE-FILLING MINIATURE ANTENNAS

DESCRIPTION

Object of the Invention

The present invention generally refers to a new family of antennas of reduced size based on an innovative geometry, the geometry of the curves named as Space-Filling Curves (SFC). An antenna is said to be a small antenna (a miniature antenna) when it can be fitted in a small space compared to the operating wavelength. More precisely, the radiansphere is taken as the reference for classifying an antenna as being small. The radiansphere is an imaginary sphere of radius equal to the operating wavelength divided by two times π; an antenna is said to be small in terms of the wavelength when it can be fitted inside said radiansphere.

A novel geometry, the geometry of Space-Filling Curves (SFC) is defined in the present invention and it is used to shape a part of an antenna. By means of this novel technique, the size of the antenna can be reduced with respect to prior art, or alternatively, given a fixed size the antenna can operate at a lower frequency with respect to a conventional antenna of the same size.

The invention is applicable to the field of the telecommunications and more concretely to the design of antennas with reduced size.

Background and Summary of the Invention

The fundamental limits on small antennas where theoretically established by H.Wheeler and L.J.Chu in the middle 1940's. They basically stated that a small antenna has a high quality factor (Q) because of the large reactive energy stored in the antenna vicinity compared to the radiated power. Such a high quality factor yields a narrow bandwidth; in fact, the fundamental derived in such theory imposes a maximum bandwidth given a specific size of an small antenna.

Related to this phenomenon, it is also known that a small antenna features a large input reactance (either capacitive or inductive) that usually has to be compensated with an external matching/loading circuit or structure. It also means that is difficult to pack a resonant antenna into a space which is small in terms of the wavelength at resonance. Other characteristics of a small antenna are its small radiating resistance and its low efficiency.

Searching for structures that can efficiently radiate from a small space has an enormous commercial interest, especially in the environment of mobile communication devices (cellular telephony, cellular pagers, portable computers and data handlers, to name a few examples), where the size and weight of the portable equipments need to be small. According to R.C.Hansen (R.C.Hansen, "Fundamental Limitations on Antennas," Proc.IEEE, vol.69, no.2, February 1981), the performance of a small antenna depends on its ability to efficiently use the small

available space inside the imaginary radiansphere surrounding the antenna.

In the present invention, a novel set of geometries named Space-Filling Curves (hereafter SFC) are introduced for the design and construction of small antennas that improve the performance of other classical antennas described in the prior art (such as linear monopoles, dipoles and circular or rectangular loops).

Some of the geometries described in the present invention are inspired in the geometries studied already in the XIX century by several mathematicians such as Giusepe Peano and David Hilbert. In all said cases the curves were studied from the mathematical point of view but were never used for any practical engineering application.

The dimension (D) is often used to characterize highly complex geometrical curves and structures such those described in the present invention. There exists many different mathematical definitions of dimension but in the present document the box-counting dimension (which is well-known to those skilled in mathematics theory) is used to characterize a family of designs. Those skilled in mathematics theory will notice that optionally, an Iterated Function System (IFS), a Multireduction Copy Machine (MRCM) or a Networked Multireduction Copy Machine (MRCM) algorithm can be used to construct some space-filling curves as those described in the present invention.

The key point of the present invention is shaping part of the antenna (for example at least a part of the arms of a dipole, at least a part of the arm of a monopole, the perimeter of the patch of a patch antenna, the slot in a slot antenna, the loop perimeter in a loop antenna, the horn cross-section in a horn antenna, or the reflector perimeter in a reflector antenna) as a space-filling curve, that is, a curve that is large in terms of physical length but small in terms of the area in which the curve can be included. More precisely, the following definition is taken in this document for a space-filling curve: a curve composed by at least ten segments which are connected in such a way that each segment forms an angle with their neighbours, that is, no pair of adjacent segments define a larger straight segment, and wherein the curve can be optionally periodic along a fixed straight direction of space if and only if the period is defined by a non-periodic curve composed by at least ten connected segments and no pair of said adjacent and connected segments define a straight longer segment. Also, whatever the design of such SFC is, it can never intersect with itself at any point except the initial and final point (that is, the whole curve can be arranged as a closed curve or loop, but none of the parts of the curve can become a closed loop). A space-filling curve can be fitted over a flat or curved surface, and due to the angles between segments, the physical length of the curve is always larger than that of any straight line that can be fitted in the same area (surface) as said space-filling curve. Additionally, to properly shape the structure of a miniature antenna according to the present invention, the

segments of the SFC curves must be shorter than a tenth of the free-space operating wavelength.

Depending on the shaping procedure and curve geometry, some infinite length SFC can be theoretically designed to feature a Haussdorf dimension larger than their topological-dimension. That is, in terms of the classical Euclidean geometry, It is usually understood that a curve is always a one-dimension object; however when the curve is highly convoluted and its physical length is very large, the curve tends to fill parts of the surface which supports it; in that case the Haussdorf dimension can be computed over the curve (or at least an approximation of it by means of the box-counting algorithm) resulting in a number larger than unity. Such theoretical infinite curves can not be physically constructed, but they can be approached with SFC designs. The curves 8 and 17 described in and Figure 2 and Figure 5 are some examples of such SFC, that approach an ideal infinite curve featuring a dimension D = 2.

The advantage of using SFC curves in the physical shaping of the antenna is two-fold:

(a) Given a particular operating frequency or wavelength said SFC antenna can be reduced in size with respect to prior art.

(b) Given the physical size of the SFC antenna, said SFC antenna can be operated at a lower frequency (a longer wavelength) than prior art.

Brief Description of the Drawings

Figure 1 shows some particular cases of SFC curves. From an initial curve (2), other curves (1), (3) and (4) with more than 10 connected segments are formed. This particular family of curves are named hereafter SZ curves.

Figure 2 shows a comparison between two prior art meandering lines and two SFC periodic curves, constructed from the SZ curve of drawing 1.

Figure 3 shows a particular configuration of an SFC antenna. It consists on tree different configurations of a dipole wherein each of the two arms is fully shaped as an SFC curve (1).

Figure 4 shows other particular cases of SFC antennas. They consist on monopole antennas.

Figure 5 shows an example of an SFC slot antenna where the slot is shaped as the SFC in drawing 1.

Figure 6 shows another set of SFC curves (15-20) inspired on the Hilbert curve and hereafter named as Hilbert curves. A standard, non-SFC curve is shown in (14) for comparison.

Figure 7 shows another example of an SFC slot antenna based on the SFC curve (17) in drawing 6.

Figure 8 shows another set of SFC curves (24, 25, 26, 27) hereafter known as ZZ curves. A conventional squared zigzag curve (23) is shown for comparison.

Figure 9 shows a loop antenna based on curve (25) in a wire configuration (top). Below, the loop antenna 29 is printed over a dielectric substrate (10).

Figure 10 shows a slot loop antenna based on the SFC (25) in drawing 8.

Figure 11 shows a patch antenna wherein the patch perimeter is shaped according to SFC (25).

Figure 12 shows an aperture antenna wherein the aperture (33) is practiced on a conducting or superconducting structure (31), said aperture being shaped with SFC (25).

Figure 13 shows a patch antenna with an aperture on the patch based on SFC (25).

Figure 14 shows another particular example of a family of SFC curves (41, 42, 43) based on the Giusepe Peano curve. A non-SFC curve formed with only 9 segments is shown for comparison.

Figure 15 shows a patch antenna with an SFC slot based on SFC (41).

Figure 16 shows a wave-guide slot antenna wherein a rectangular waveguide (47) has one of its walls slotted with SFC curve (41).

Figure 17 shows a horn antenna, wherein the aperture and cross-section of the horn is shaped after SFC (25).

Figure 18 shows a reflector of a reflector antenna wherein the perimeter of said reflector is shaped as SFC (25).

Figure 19 shows a family of SFC curves (51, 52, 53) based on the Giusepe Peano curve. A non-SFC curve formed with only nine segments is shown for comparison (50).

Figure 20 shows another family of SFC curves (55, 56, 57, 58). A non-SFC curve (54) constructed with only five segments is shown for comparison.

Figure 21 shows two examples of SFC loops (59, 60) constructed with SFC (57).

Figure 22 shows a family of SFC curves (61, 62, 63, 64) named here as HilbertZZ curves.

Figure 23 shows a family of SFC curves (66, 67, 68) named here as Peanodec curves. A non-SFC curve (65) constructed with only nine segments is shown for comparison.

Figure 24 shows a family of SFC curves (70, 71, 72) named here as Peanoinc curves. A non-SFC curve (69) constructed with only nine segments is shown for comparison.

Figure 25 shows a family of SFC curves (73, 74, 75) named here as PeanoZZ curves. A non-SFC curve (23) constructed with only nine segments is shown for comparison.

Detailed Description of the Preferred Embodiments

Figure 1 and Figure 2 show some examples of SFC curves. Drawings (1), (3) and (4) in Figure 1 show three examples of SFC curves named SZ curves. A curve that is not an SFC since it is only composed of 6 segments is shown in drawing (2) for comparison. The drawings (7) and (8) in Figure 2 show another two particular examples of SFC curves, formed from the periodic repetition of a motive including the SFC curve (1). It is important noticing the substantial difference between these examples of SFC curves and some examples of periodic, meandering and not SFC curves such as those in drawings (5) and (6) in Figure 2. Although curves (5) and (6) are composed by more than 10 segments, they can be substantially considered periodic along a straight direction (horizontal direction) and the motive that defines a period or repetition cell is constructed with less than 10 segments (the period in drawing (5) includes only four segments, while the period of the curve (6) comprises nine segments) which contradicts the definition of SFC curve introduced in the present invention. SFC curves are substantially

more complex and pack a longer length in a smaller space; this fact in conjunction with the fact that each segment composing and SFC curve is electrically short (shorter than a tenth of the free-space operating wavelength as claimed in this invention) play a key role in reducing the antenna size. Also, the class of folding mechanisms used to obtain the particular SFC curves described in the present invention are important in the design of miniature antennas.

Figure 3 describes a preferred embodiment of an SFC antenna. The three drawings display different configurations of the same basic dipole. A two-arm antenna dipole is constructed comprising two conducting or superconducting parts, each part shaped as an SFC curve. For the sake of clarity but without loss of generality, a particular case of SFC curve (the SZ curve (1) of Figure 1) has been chosen here; other SFC curves as for instance, those described in Figs. 1, 2, 6, 8, 14, 19, 20, 21, 22, 23, 24 or 25 could be used instead. The two closest tips of the two arms form the input terminals (9) of the dipole. The terminals (9) have been drawn as conducting or superconducting circles, but as it is clear to those skilled in the art, such terminals could be shaped following any other pattern as long as they are kept small in terms of the operating wavelength. Also, the arms of the dipoles can be rotated and folded in different ways to finely modify the input impedance or the radiation properties of the antenna such as, for instance, polarization. Another preferred embodiment of an SFC dipole is also shown in Figure 3, where the conducting or

superconducting SFC arms are printed over a dielectric substrate (10); this method is particularly convenient in terms of cost and mechanical robustness when the SFC curve is long. Any of the well-known printed circuit fabrication techniques can be applied to pattern the SFC curve over the dielectric substrate. Said dielectric substrate can be for instance a glass-fibre board, a teflon based substrate (such as Cuclad®) or other standard radiofrequency and microwave substrates (as for instance Rogers 4003® or Kapton®). The dielectric substrate can even be a portion of a window glass if the antenna is to be mounted in a motor vehicle such as a car, a train or an air-plane, to transmit or receive radio, TV, cellular telephone (GSM 900, GSM 1800, UMTS) or other communication services electromagnetic waves. Of course, a balun network can be connected or integrated at the input terminals of the dipole to balance the current distribution among the two dipole arms.

Another preferred embodiment of an SFC antenna is a monopole configuration as shown in Figure 4. In this case one of the dipole arms is substituted by a conducting or superconducting counterpoise or ground plane (12). A handheld telephone case, or even a part of the metallic structure of a car, train or can act as such a ground counterpoise. The ground and the monopole arm (here the arm is represented with SFC curve (1), but any other SFC curve could be taken instead) are excited as usual in prior art monopoles by means of, for instance, a transmission line (11). Said transmission line is formed by two conductors, one of the conductors is connected to

the ground counterpoise while the other is connected to a point of the SFC conducting or superconducting structure. In the drawings of Figure 4, a coaxial cable (11) has been taken as a particular case of transmission line, but it is clear to any skilled in the art that other transmission lines (such as for instance a microstrip arm) could be used to excite the monopole. Optionally, and following the scheme described in Figure 3, the SFC curve can be printed over a dielectric substrate (10).

Another preferred embodiment of an SFC antenna is a slot antenna as shown, for instance in Figures 5, 7 and 10. In Figure 5, two connected SFC curves (following the pattern (1) of Figure 1) form an slot or gap impressed over a conducting or superconducting sheet (13). Such sheet can be, for instance, a sheet over a dielectric substrate in a printed circuit board configuration, a transparent conductive film such as those deposited over a glass window to protect the interior of a car from heating infrared radiation, or can even be part of the metallic structure of a handheld telephone, a car, train, boat or airplane. The exciting scheme can be any of the well known in conventional slot antennas and it does not become an essential part of the present invention. In all said three figures, a coaxial cable (11) has been used to excite the antenna, with one of the conductors connected to one side of the conducting sheet and the other one connected at the other side of the sheet across the slot. A microstrip transmission line could be used, for instance, instead of the coaxial cable.

To illustrate that several modifications of the antenna that can be done based on the same principle and spirit of the present invention, a similar example is shown in Figure 7, where another curve (the curve (17) from the Hilbert family) is taken instead. Notice that neither in Figure 5, nor in Figure 7 the slot reaches the borders of the conducting sheet, but in another embodiment the slot can be also designed to reach the boundary of said sheet, breaking said sheet in two separate conducting sheets.

Figure 10 describes another possible embodiment of an slot SFC antenna. It is also an slot antenna in a closed loop configuration. The loop is constructed for instance by connecting four SFC gaps following the pattern of SFC (25) in Figure 8 (it is clear that other SFC curves could be used instead according to the spirit and scope of the present invention). The resulting closed loop determines the boundary of a conducting or superconducting island surrounded by a conducting or superconducting sheet. The slot can be excited by means of any of the well-known conventional techniques; for instance a coaxial cable (11) can be used, connecting one of the outside conductor to the conducting outer sheet and the inner conductor to the inside conducting island surrounded by the SFC gap. Again, such sheet can be, for example, a sheet over a dielectric substrate in a printed circuit board configuration, a transparent conductive film such as those deposited over a glass window to protect the interior of a car from heating infrared radiation, or can even be part of the metallic structure of a handheld telephone, a car, train, boat or

air-plane. The slot can be even formed by the gap between two close but not co-planar conducting island and conducting sheet; this can be physically implemented for instance by mounting the inner conducting island over a surface of the optional dielectric substrate, and the surrounding conductor over the opposite surface of said substrate.

The slot configuration is not, of course, the only way of implementing an SFC loop antenna. A closed SFC curve made of a superconducting or conducting material can be used to implement a wire SFC loop antenna as shown in another preferred embodiment as that of Figure 9. In this case, a portion of the curve is broken such as the two resulting ends of the curve form the input terminals (9) of the loop. Optionally, the loop can be printed also over a dielectric substrate (10). In case a dielectric substrate is used, a dielectric antenna can be also constructed by etching a dielectric SFC pattern over said substrate, being the dielectric permitivity of said dielectric pattern higher than that of said substrate.

Another preferred embodiment is described in Figure 11. It consists on a patch antenna, with the conducting or superconducting patch (30) featuring an SFC perimeter (the particular case of SFC (25) has been used here but it is clear that other SFC curves could be used instead). The perimeter of the patch is the essential part of the invention here, being the rest of the antenna conformed, for example, as other conventional patch antennas: the patch antenna comprises a conducting or superconducting

ground-plane (31) or ground counterpoise, an the conducting or superconducting patch which is parallel to said ground-plane or ground-counterpoise. The spacing between the patch and the ground is typically below (but not restricted to) a quarter wavelength. Optionally, a low-loss dielectric substrate (10) (such as glass-fibre, a teflon substrate such as Cuclad® or other commercial materials such as Rogers® 4003) can be place between said patch and ground counterpoise. The antenna feeding scheme can be taken to be any of the well-known schemes used in prior art patch antennas, for instance: a coaxial cable with the outer conductor connected to the ground-plane and the inner conductor connected to the patch at the desired input resistance point (of course the typical modifications including a capacitive gap on the patch around the coaxial connecting point or a capacitive plate connected to the inner conductor of the coaxial placed at a distance parallel to the patch, and so on can be used as well); a microstrip transmission line sharing the same ground-plane as the antenna with the strip capacitively coupled to the patch and located at a distance below the patch, or in another embodiment with the strip placed below the ground-plane and coupled to the patch through an slot, and even a microstrip transmission line with the strip co-planar to the patch. All these mechanisms are well known from prior art and do not constitute an essential part of the present invention. The essential part of the present invention is the shape of the antenna (in this case the SFC perimeter of the patch) which contributes to reducing the antenna size with respect to prior art configurations.

Other preferred embodiments of SFC antennas based also on the patch configuration are disclosed in Figure 13 and Figure 15. They consist on a conventional patch antenna with a polygonal patch (30) (squared, triangular, pentagonal, hexagonal, rectangular, or even circular, to name just a few examples), with an SFC curve shaping a gap on the patch. Such an SFC line can form an slot or spur-line (44) over the patch (as seen in Figure 15) contributing this way in reducing the antenna size and introducing new resonant frequencies for a multiband operation, or in another preferred embodiment the SFC curve (such as (25) defines the perimeter of an aperture (33) on the patch (30) (Figure 13). Such an aperture contributes significantly to reduce the first resonant frequency of the patch with respect to the solid patch case, which significantly contributes to reducing the antenna size. Said two configurations, the SFC slot and the SFC aperture cases can of course be use also with SFC perimeter patch antennas as for instance the one (30) described in Figure 11.

At this point it becomes clear to those skilled in the art what is the scope and spirit of the present invention and that the same SFC geometric principle can be applied in an innovative way to all the well known, prior art configurations. More examples are given in Figures 12, 16, 17 and 18.

Figure 12 describes another preferred embodiment of an SFC antenna. It consists on an aperture antenna, said aperture being characterized by its SFC perimeter, said

aperture being impressed over a conducting ground-plane or ground-counterpoise (34), said ground-plane of ground-counterpoise consisting, for example, on a wall of a waveguide or cavity resonator or a part of the structure of a motor vehicle (such as a car, a lorry, an airplane or a tank). The aperture can be fed by any of the conventional techniques such as a coaxial cable (11), or a planar microstrip or strip-line transmission line, to name a few.

Figure 16 shows another preferred embodiment where the SFC curves (41) are slotted over a wall of a waveguide (47) of arbitrary cross-section. This way and slotted waveguide array can be formed, with the advantage of the size compressing properties of the SFC curves.

Figure 17 depicts another preferred embodiment, in this case a horn antenna (48) where the cross-section of the antenna is an SFC curve (25). In this case, the benefit comes not only from the size reduction property of SFC geometries, but also from the broadband behavior that can be achieved by shaping the horn cross-section. Primitive versions of these techniques have been already developed in the form of Ridge horn antennas. In said prior art cases, a single squared tooth introduced in at least two opposite walls of the horn is used to increase the bandwidth of the antenna. The richer scale structure of an SFC curve further contributes to a bandwidth enhancement with respect to prior art.

Figure 18 describes another typical configuration of antenna, a reflector antenna (49), with the newly disclosed approach of shaping the reflector perimeter with an SFC curve. The reflector can be either flat or curve, depending on the application or feeding scheme (in for instance a reflectarray configuration the SFC reflectors will preferably be flat, while in focus fed dish reflectors the surface bounded by the SFC curve will preferably be curved approaching a parabolic surface). Also, within the spirit of SFC reflecting surfaces, Frequency Selective Surfaces (FSS) can be also constructed by means of SFC curves; in this case the SFC are used to shape the repetitive pattern over the FSS. In said FSS configuration, the SFC elements are used in an advantageous way with respect to prior art because the reduced size of the SFC patterns allows a closer spacing between said elements. A similar advantage is obtained when the SFC elements are used in an antenna array in an antenna reflectarray.

Having illustrated and described the principles of our invention in several preferred embodiments thereof, it should be readily apparent to those skilled in the art that the invention can be modified in arrangement and detail without departing from such principles. We claim all modifications coming within the spirit and scope of the accompanying claims.

CLAIMS

1.- An antenna in which at least one of its parts is shaped as a space-filling curve (hereafter SFC), being said SFC defined as a curve composed by at least ten connected straight segments, wherein said segments are smaller than a tenth of the operating free-space wave length and they are spatially arranged in such a way that none of said adjacent and connected segments form another longer straight segment, wherein non of said segments intersect to each other except optionally at the tips of the curve, wherein the corners formed by each pair of said adjacent segments can be optionally rounded or smoothed otherwise, and wherein the curve can be optionally periodic along a fixed straight direction of space if and only if the period is defined by a non-periodic curve composed by at least ten connected segments and no pair of said adjacent and connected segments define a straight longer segment. Optionally the antenna includes a network between the radiating element and the input connector or transmission line, being said network either a matching network, an impedance transformer network, a balun network, a filter network, a diplexer network or a duplexer network.

2.- An antenna in which at least one of its parts is shaped as a space-filling curve (SFC), wherein said SFC features a box-counting dimension larger than one, being said box-counting dimension computed as usual as the slope of the straight portion of a log-log graph, wherein such a

straight portion is substantially defined as a straight segment over at least an octave of scales on the horizontal axes of the log-log graph. Optionally the antenna includes a network between the radiating element and the input connector, being said network either a matching network, an impedance transformer network, a balun network, a filter network, a diplexer network or a duplexer network.

3.- An antenna in which at least one of its parts is shaped either as a Hilbert or a Peano curve. Optionally the antenna includes a network between the radiating element and the input connector, being said network either a matching network, an impedance transformer network, a balun network, a filter network, a diplexer network or a duplexer network.

4.- An antenna in which at least one of its parts is shaped either as an SZ, ZZ, Hilbert2Z, Peanoinc, Peanodec or PeanoZZ curve. Optionally the antenna includes a network between the radiating element and the input connector, being said network either a matching network, an impedance transformer network, a balun network, a filter network, a diplexer network or a duplexer network.

5.- A dipole antenna comprising two conducting or superconducting arms in which at least a part of at least one of the arms of the dipole is shaped either as an SFC, Hilbert, Peano, Hilbert2Z, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4.

6.- A monopole antenna comprising a radiating arm and a ground counterpoise in which at least a part of said is shaped either as an SFC, Hilbert, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4.

7.- A slot antenna comprising at least a conducting or superconducting surface, wherein said surface includes a slot, wherein said slot is shaped either as an SFC, Hilbert, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4, wherein said slot can be filled of backed by a dielectric substrate and wherein said conducting or superconducting surface including said slot is either a wall of a waveguide, a wall of a cavity resonator, a conducting film over a glass of a window in a motor vehicle, or part of a metallic structure of the motor vehicle.

8.- A loop antenna comprising a conducting or superconducting wire wherein at least a portion of the wire forming the loop is shaped either as an SFC, Hilbert, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4, or alternatively comprising a conducting or superconducting surface with a slot or gap loop impressed on said conducting or superconducting surface, wherein part of the slot or gap loop is shaped either as an SFC, Hilbert, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4 or 7.

9.- A patch antenna comprising at least a conducting or superconducting ground-plane and a conducting or superconducting patch parallel to said ground-plane characterized by the perimeter of the patch which is shaped either as an SFC, Hilbert, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4 or characterized by an slot or aperture on the patch, being said slot or aperture perimeter shaped either as an SFC, Hilbert, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4.

10.- An aperture antenna comprising at least a conducting or superconducting surface and an aperture on said surface wherein the aperture is characterized by its perimeter which is shaped either as an SFC, Hilbert, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4 and wherein said conducting or superconducting surface including said slot is either a wall of a waveguide, a wall of a cavity resonator, a transparent conducting film over a glass of a window in a motor vehicle, or part of a metallic structure of the motor vehicle, wherein said slot can be filled of backed by a dielectric substrate.

11.- A horn antenna characterized by the cross-section of the horn which is shaped either as an SFC, Hilbert, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4.

12.- A reflector antenna characterized by the perimeter of the reflector which is shaped either as an SFC, Hilbert, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4.

13.- A frequency selective surface (FSS) comprising a conducting or superconducting surface, wherein such surface is impressed with at least an slot, being said slot shaped either as an SFC, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4 or wherein said FSS comprises a dielectric surface in which a conducting or superconducting structure is printed over using any of the manufacturing techniques known in the previous art, said printed structures are characterized by its shape which is in part either an SFC, Peano, HilbertZZ, SZ, Peanoinc, Peanodec, PeanoZZ, or ZZ curve according to claim 1,2,3 or 4.

14.- A set of space-filling antennas according to previous claims wherein most of the antennas are fed with signal at a given frequency forming an array of SFC antennas, or where at least two of the antennas of said antenna set oporate at different frequencies to give coverage to different communications services, wherein said antennas in any of the described configurations can be simultaneously fed by means of a distribution or diplexer network respectively.

15.- A space-filling antenna according to previous claims characterized by its size which is smaller than the

size of a triangular, rectangular, circular, pentagonal or hexagonal antenna in the same monopole, dipole, patch, slot, aperture, horn or reflector configuration operating at the same frequency.

16.- A method for determining and shaping a characteristic part of an antenna consisting on choosing a curve as the basic shape for said part, being said curve characterized by its constructing algorithms, said algorithms consisting on Iterated Function Systems (IFS), Multy Reduction Copy Machine (MRCM), Networked Multi Reduction Copy Machine (NMRCM) or a combination of said mathematical algorithms.

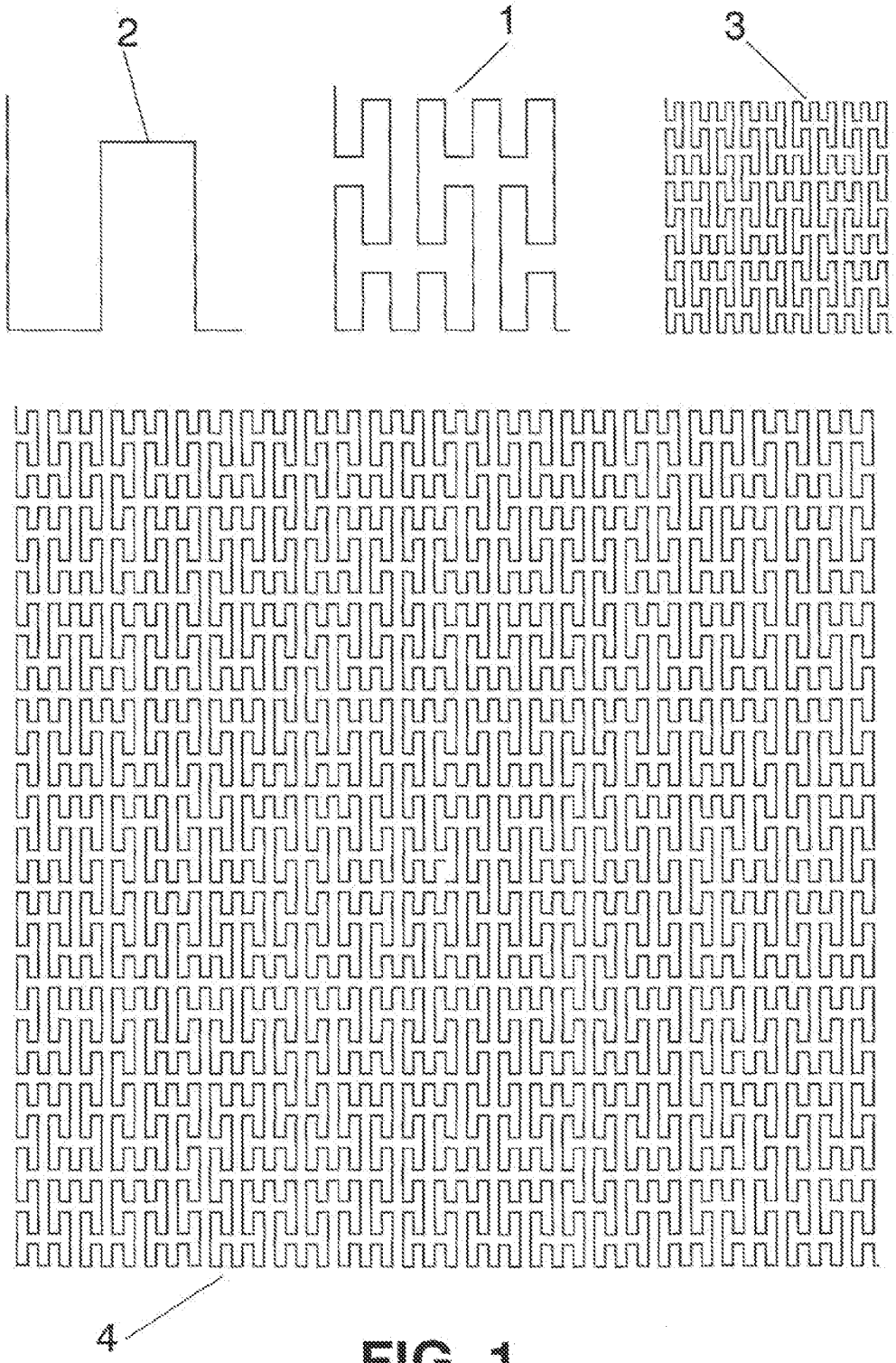


FIG. 1

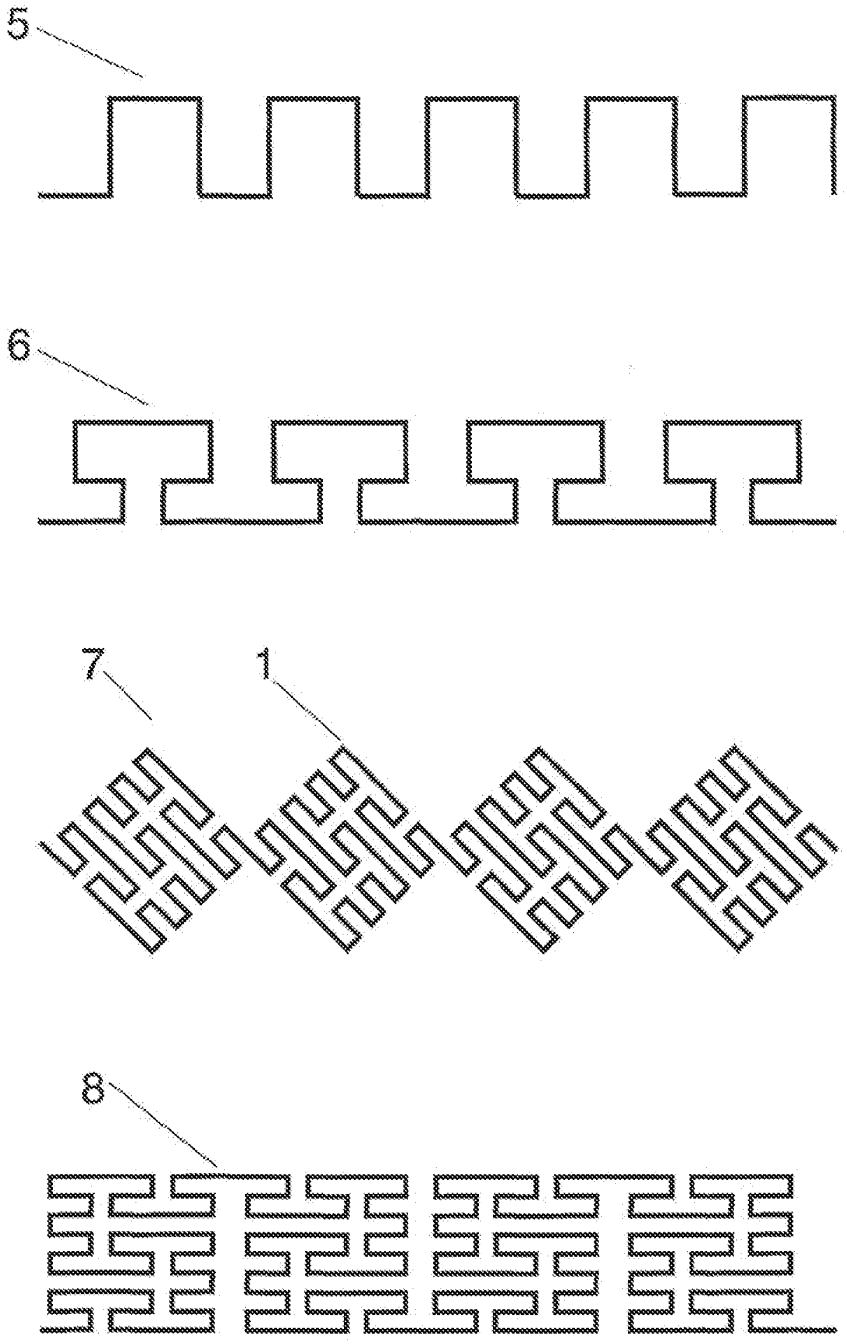


FIG. 2

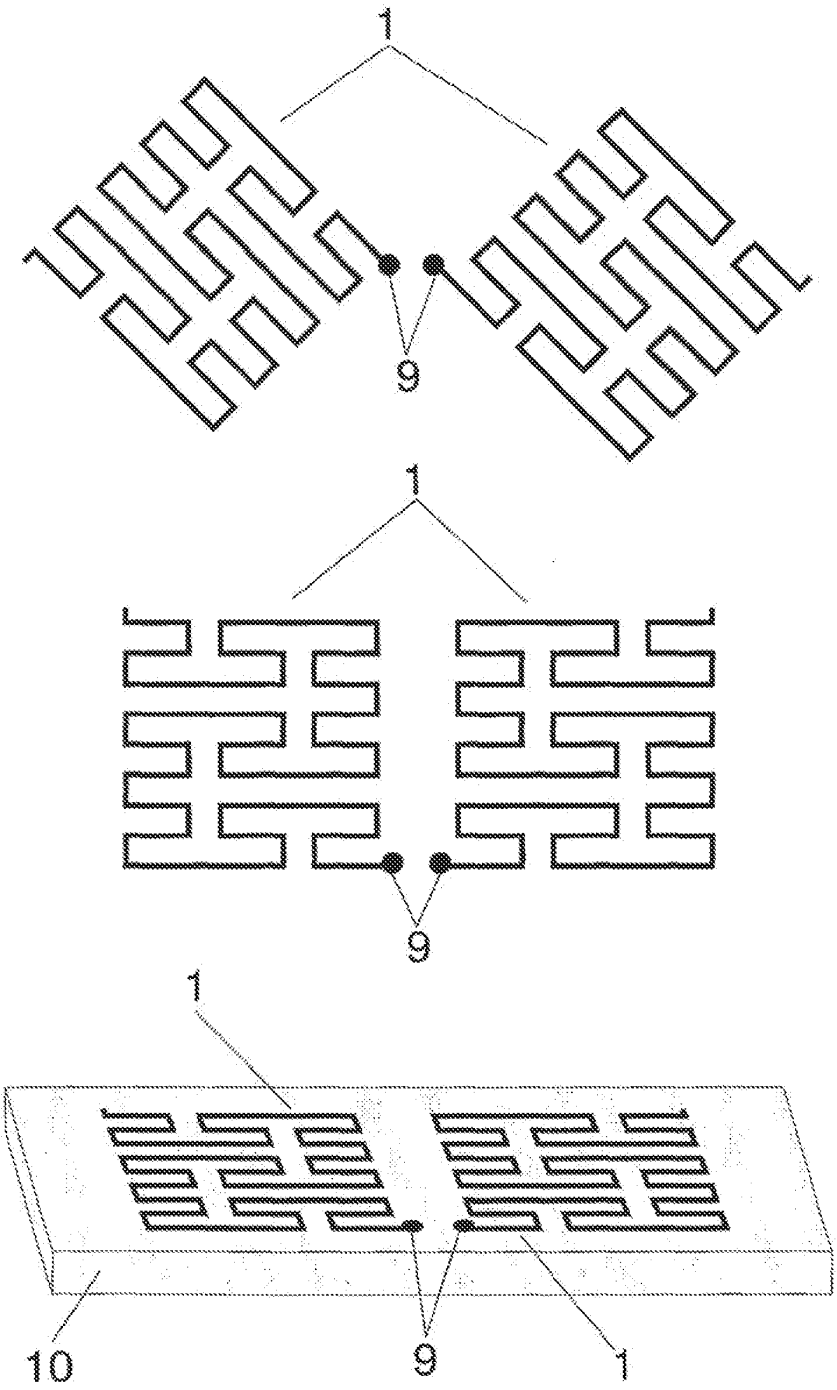


FIG. 3

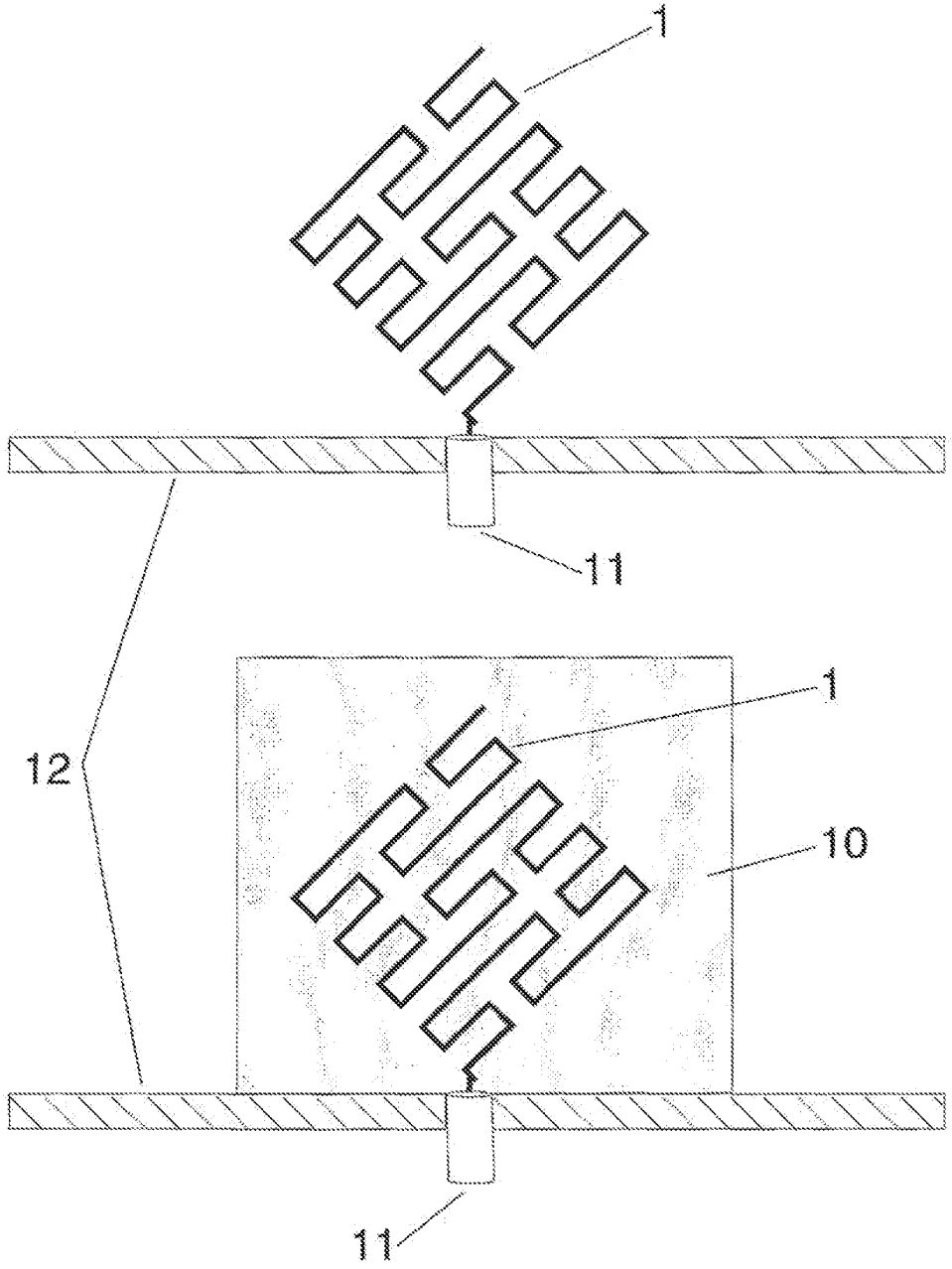


FIG. 4

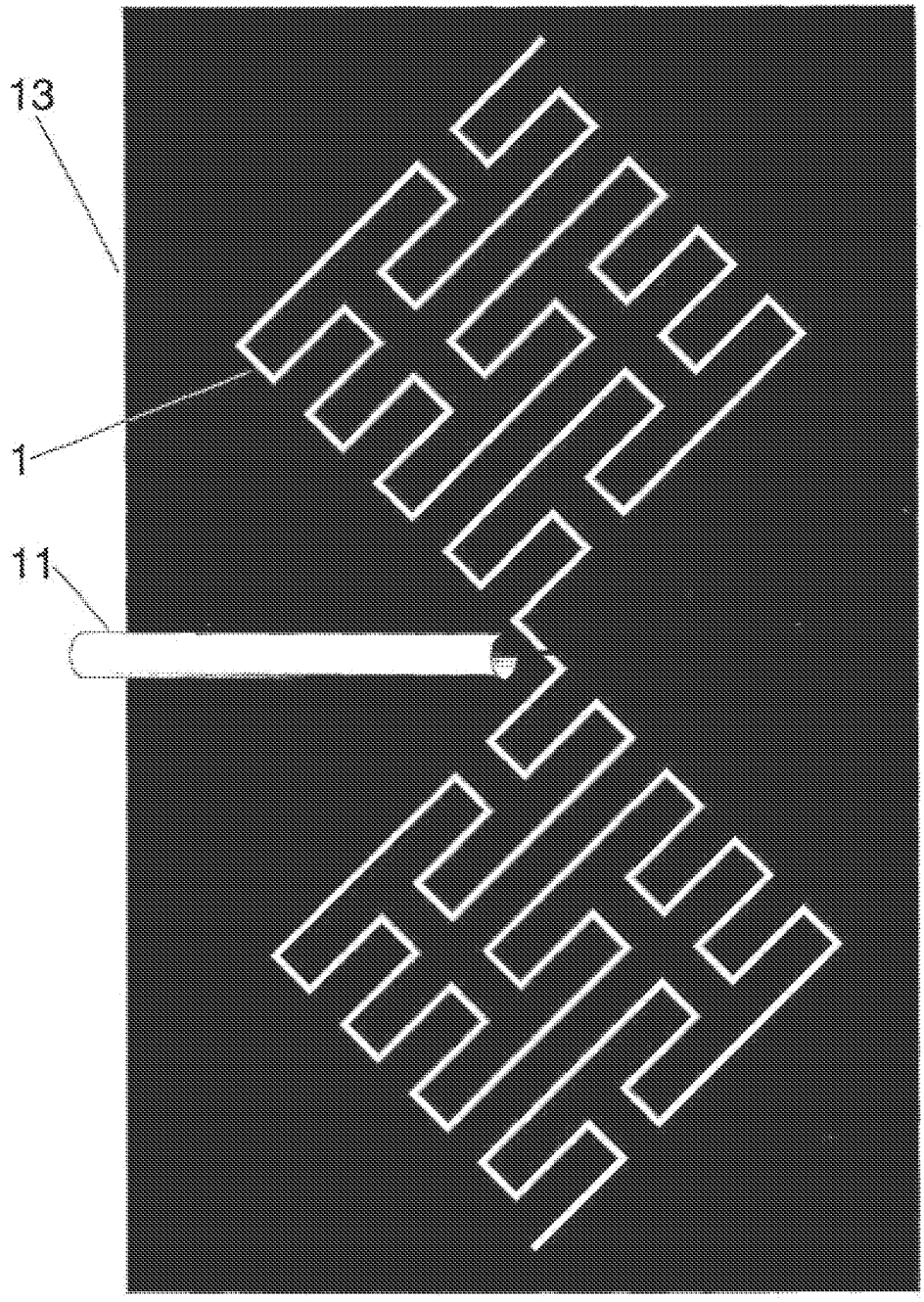


FIG. 5

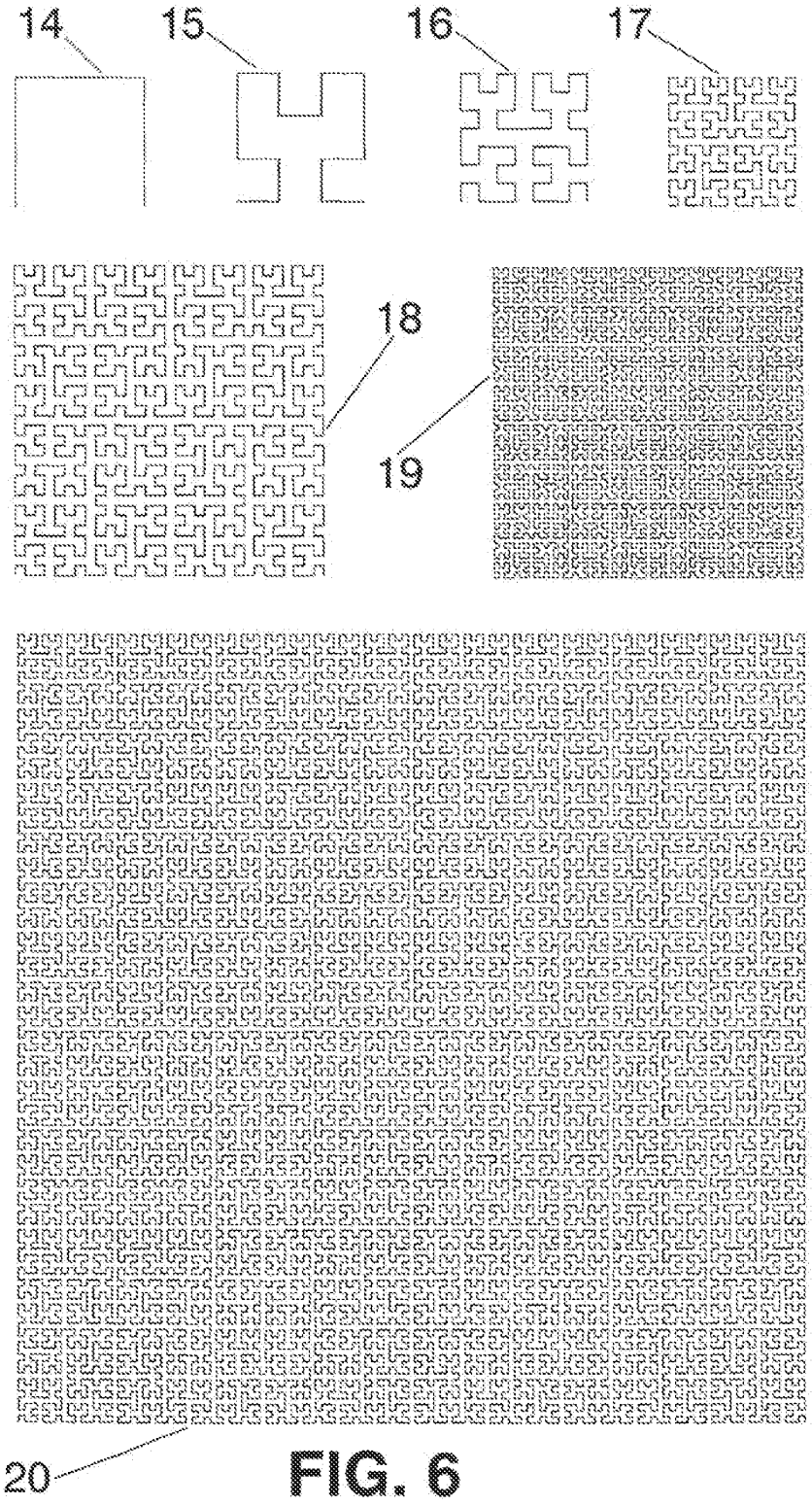


FIG. 6

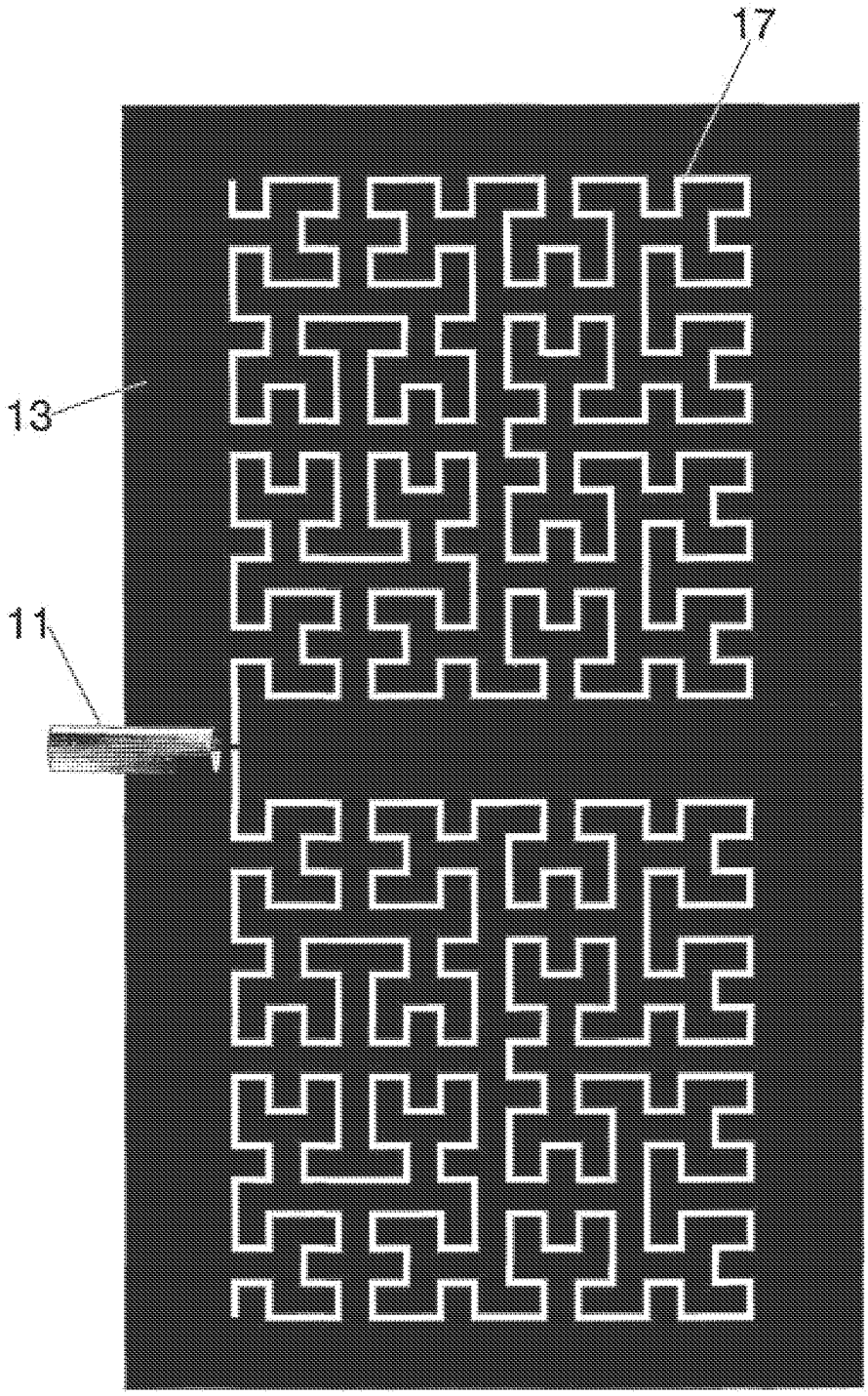


FIG. 7

SUBSTITUTE SHEET (RULE 26)

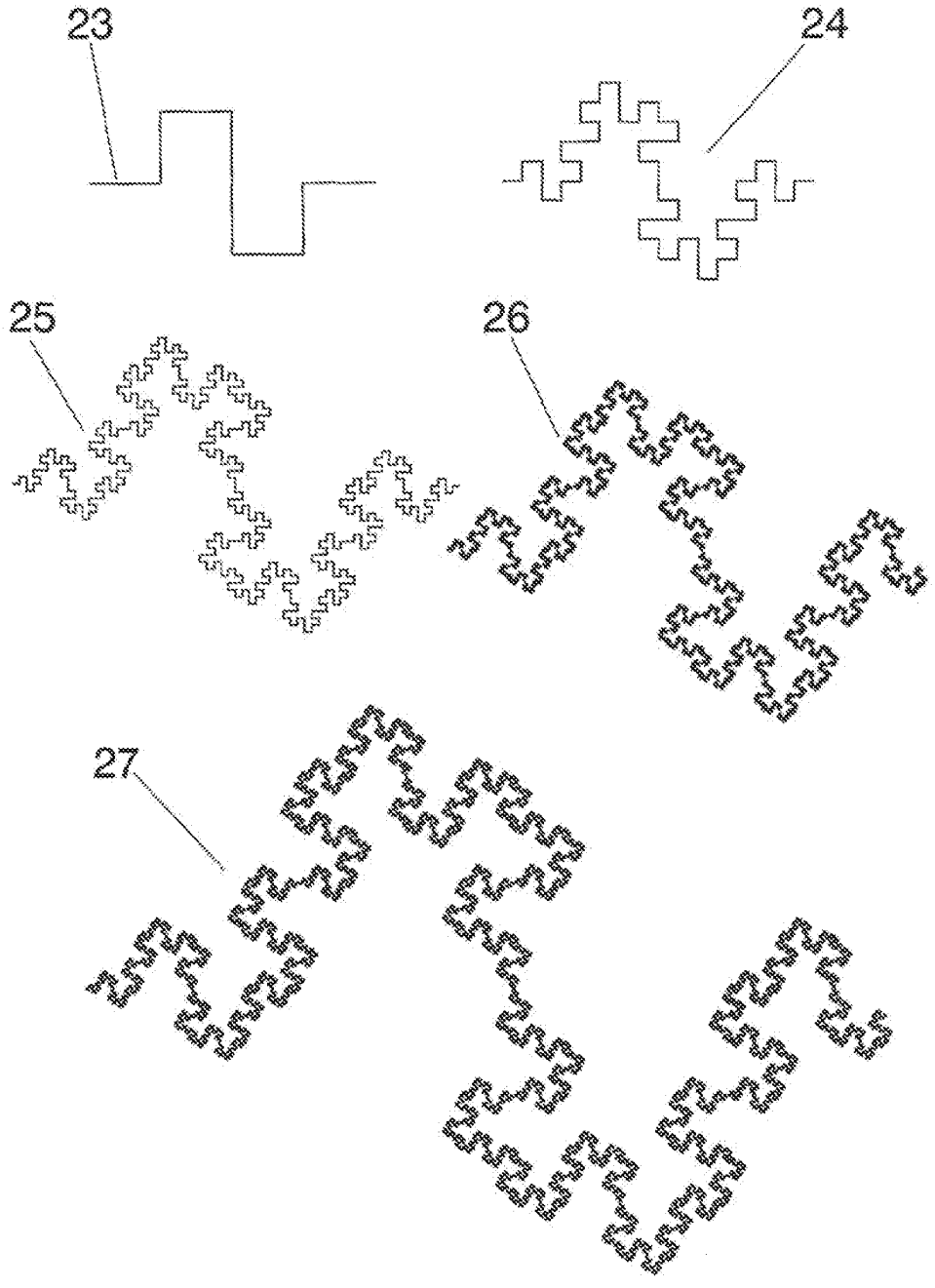


FIG. 8

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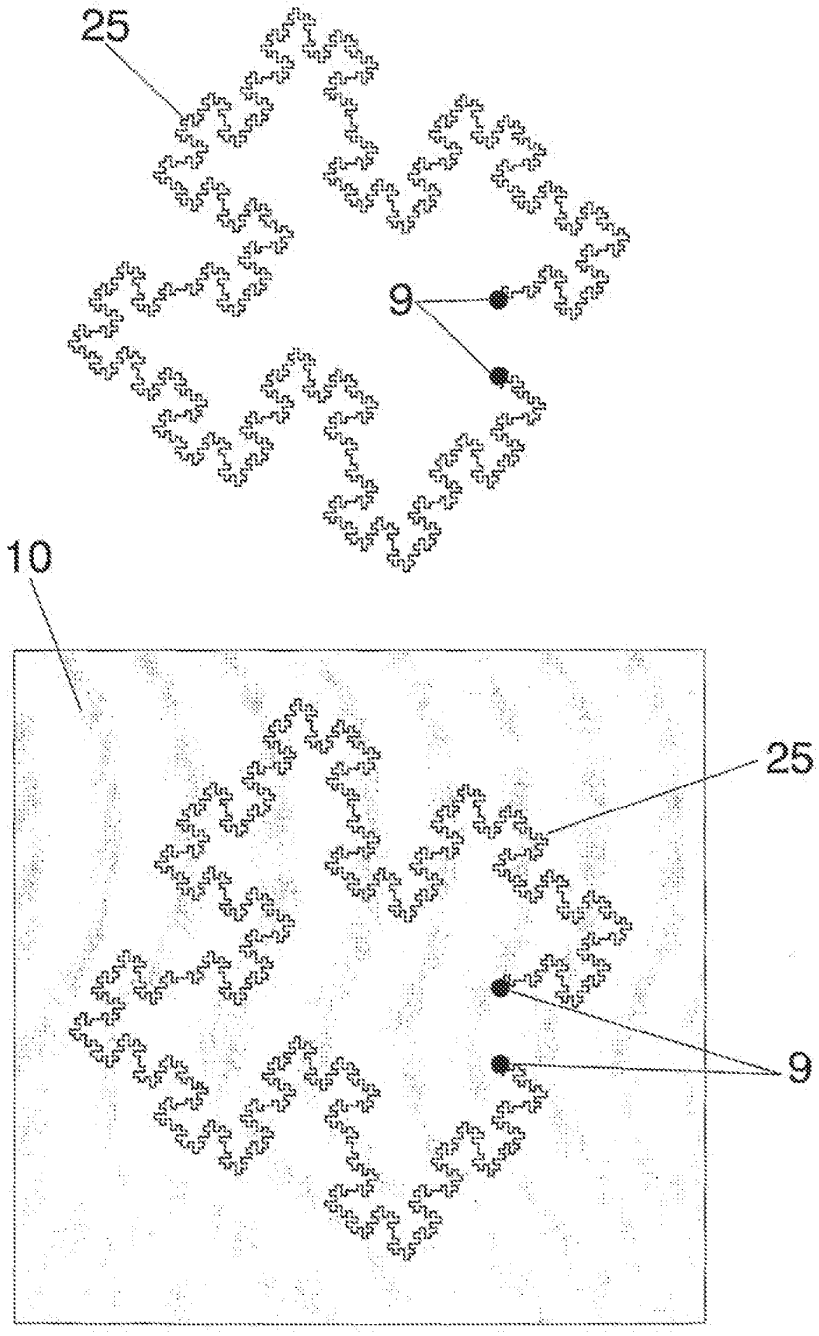


FIG. 9

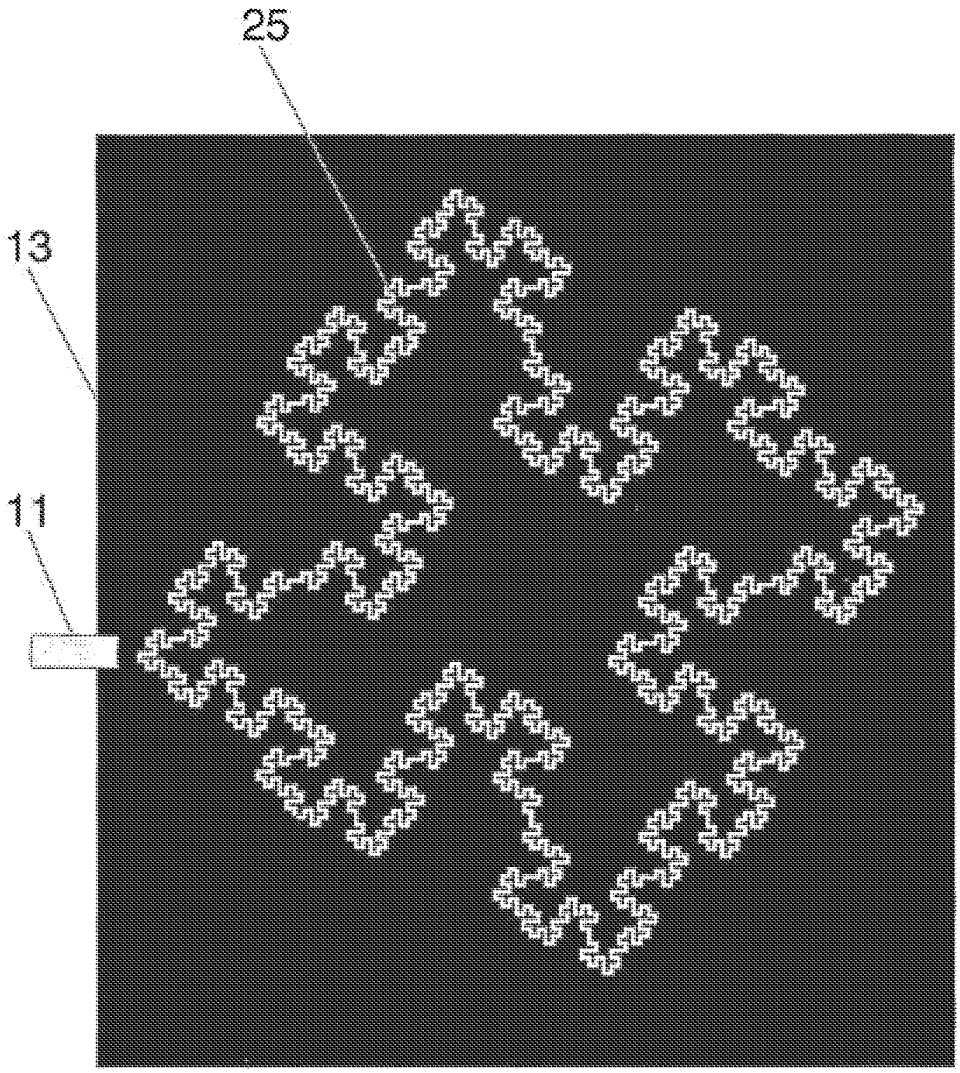


FIG. 10

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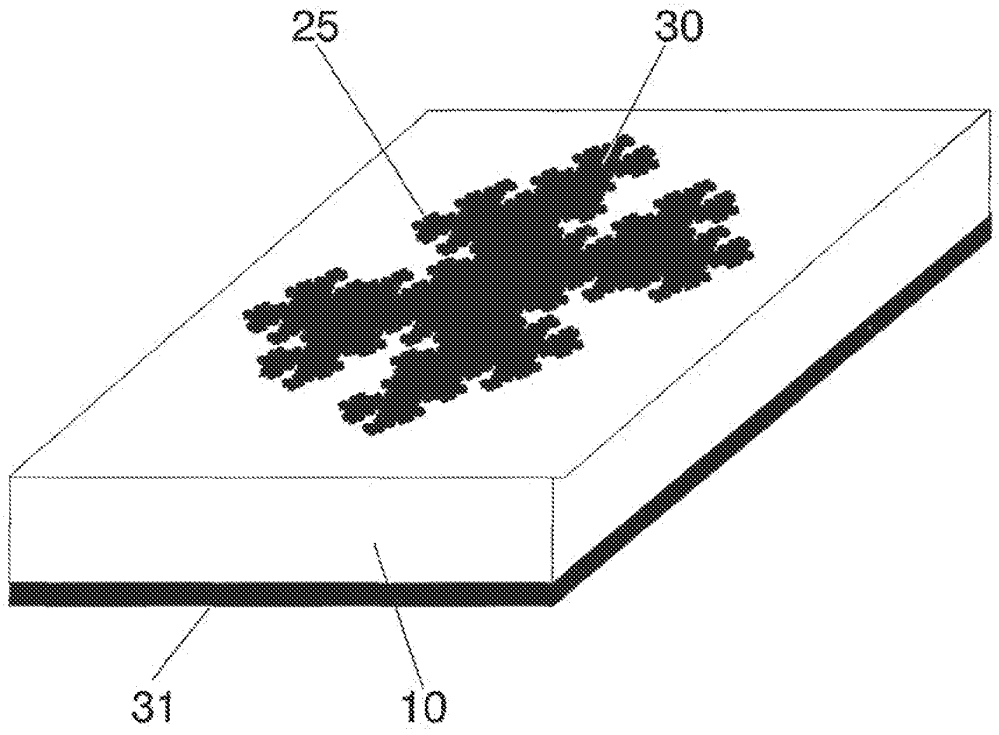


FIG. 11

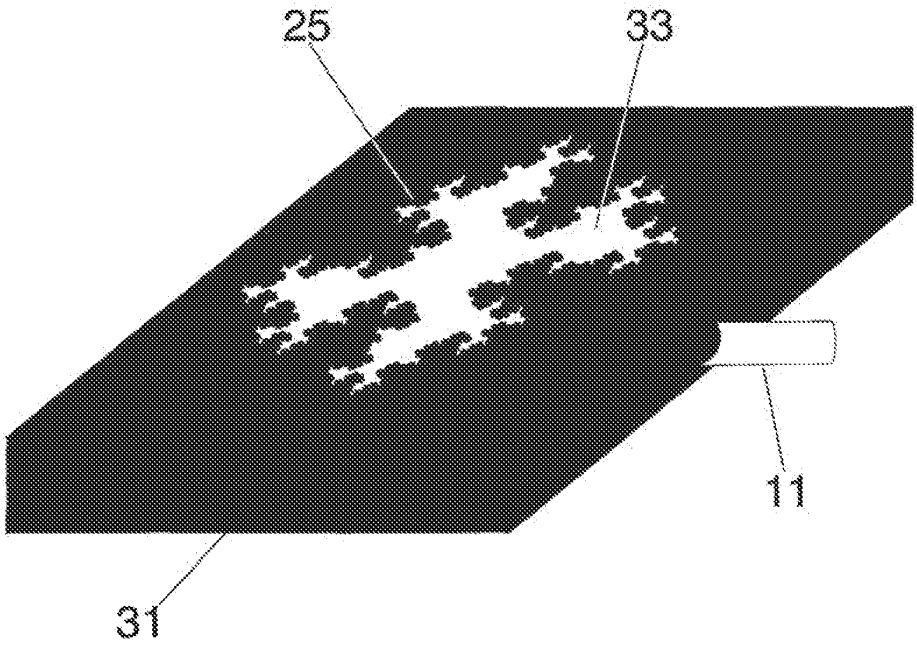


FIG. 12

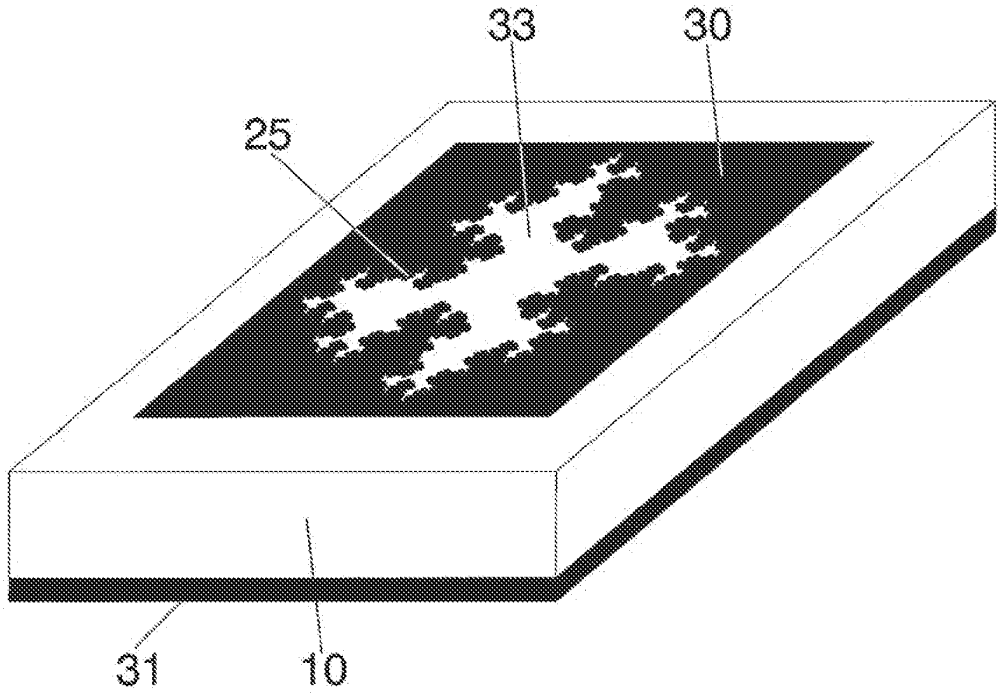


FIG. 13

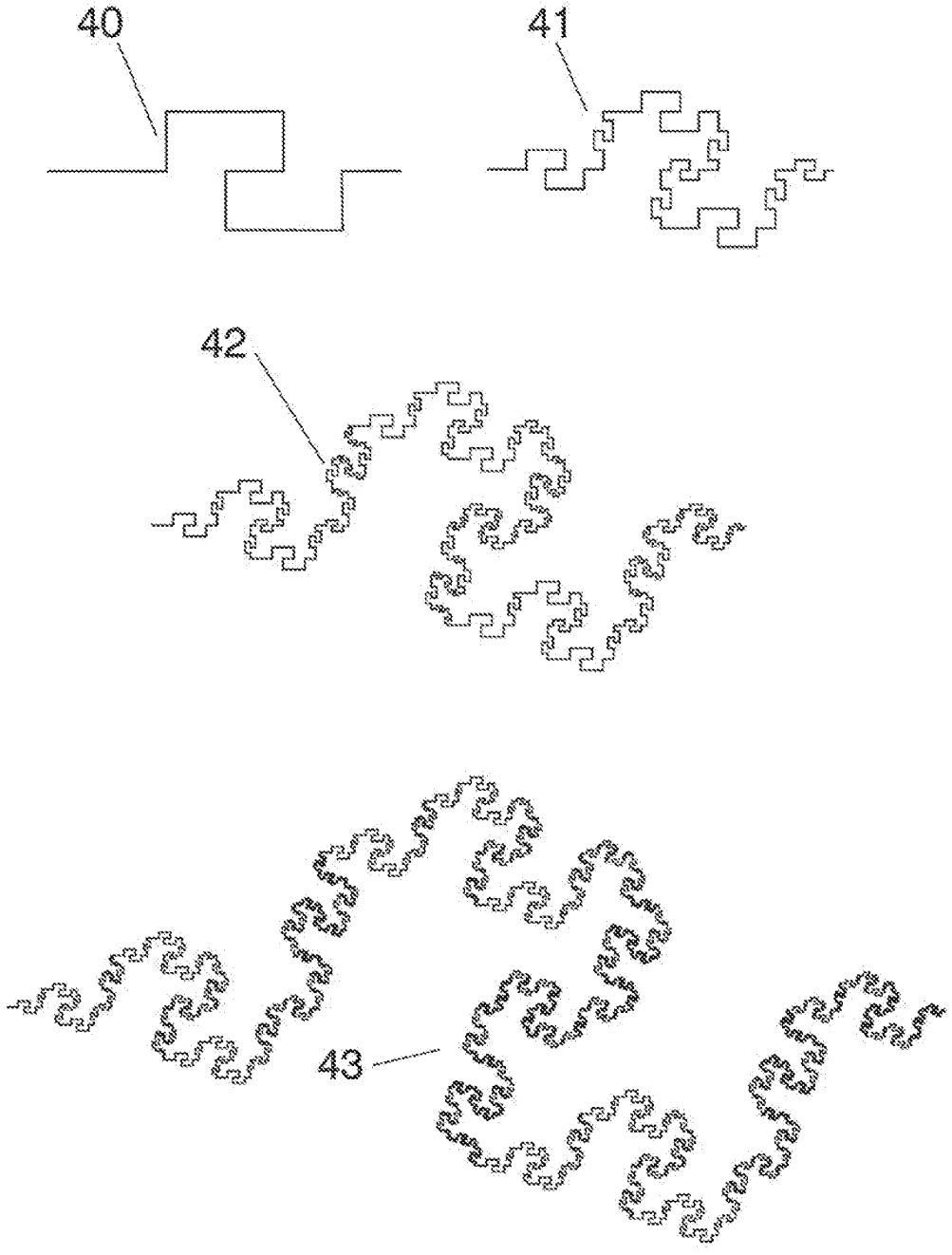


FIG. 14

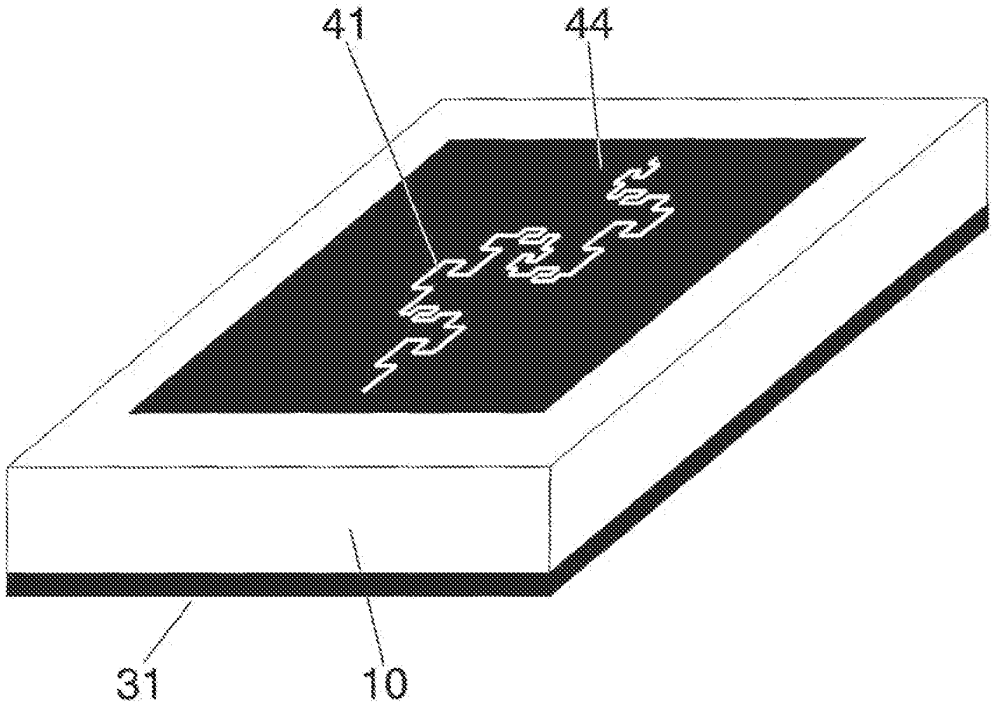


FIG. 15

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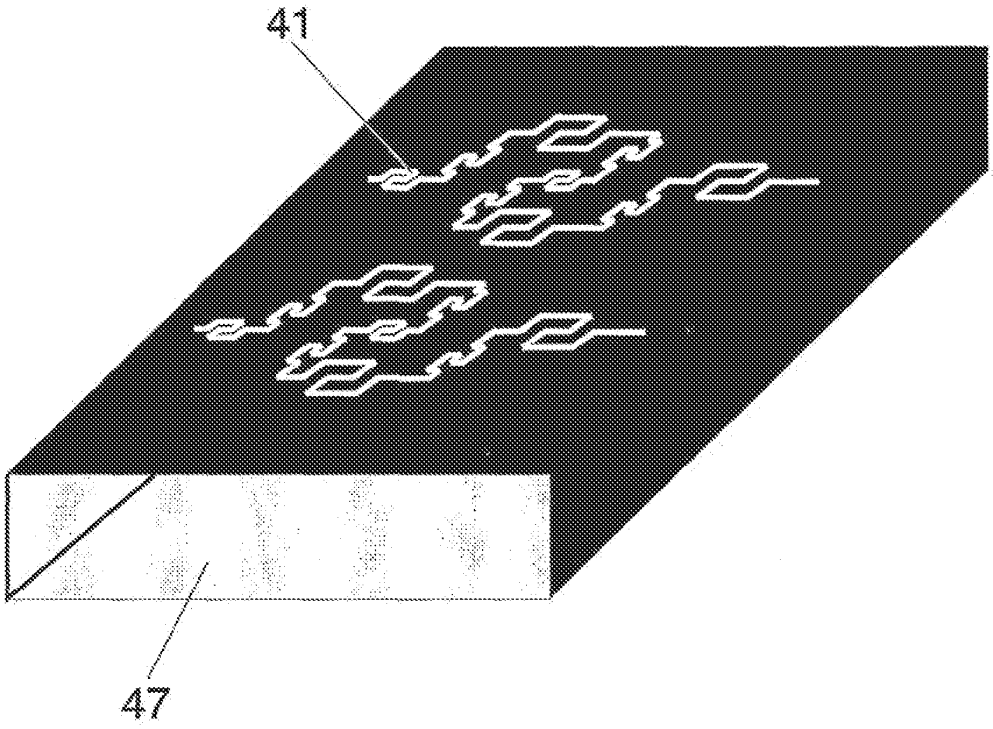


FIG. 16

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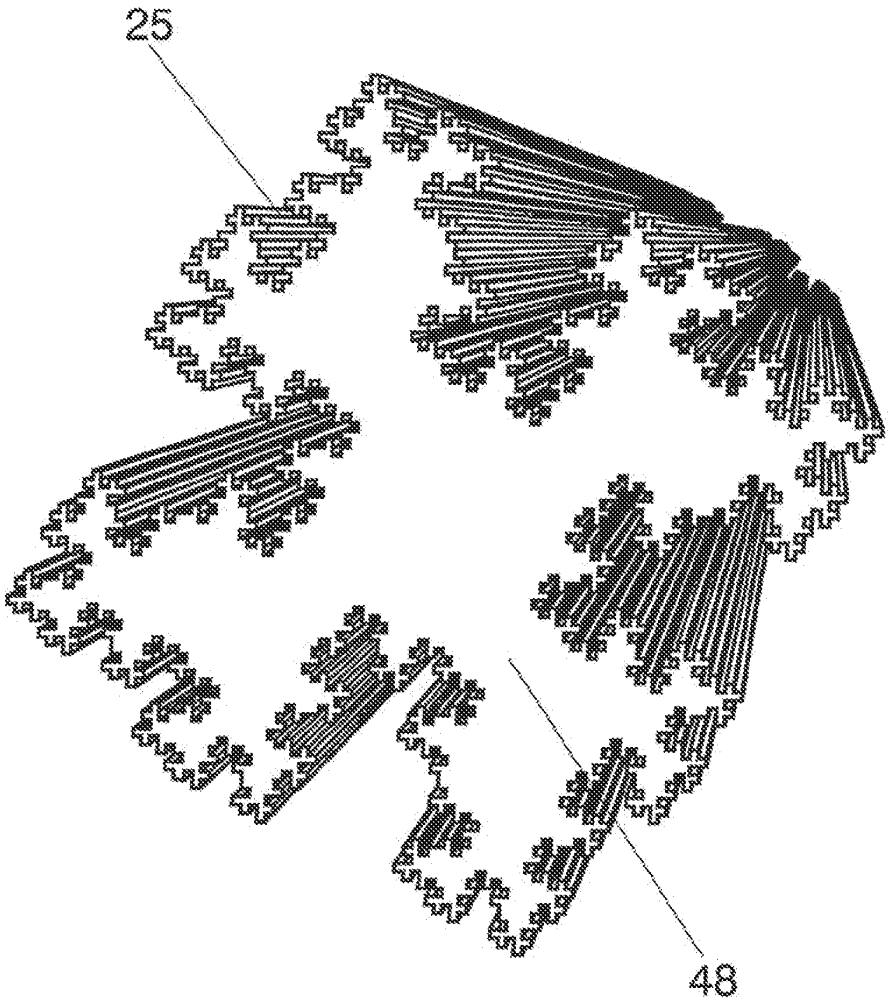


FIG. 17

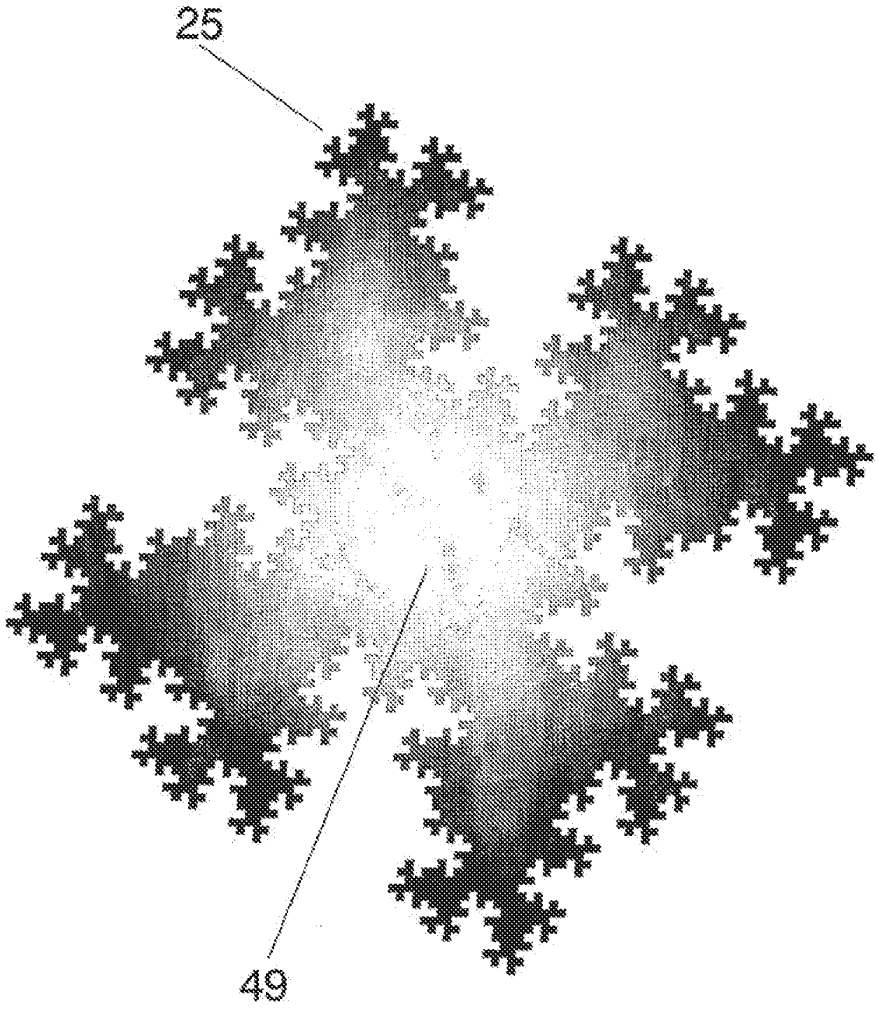


FIG. 18

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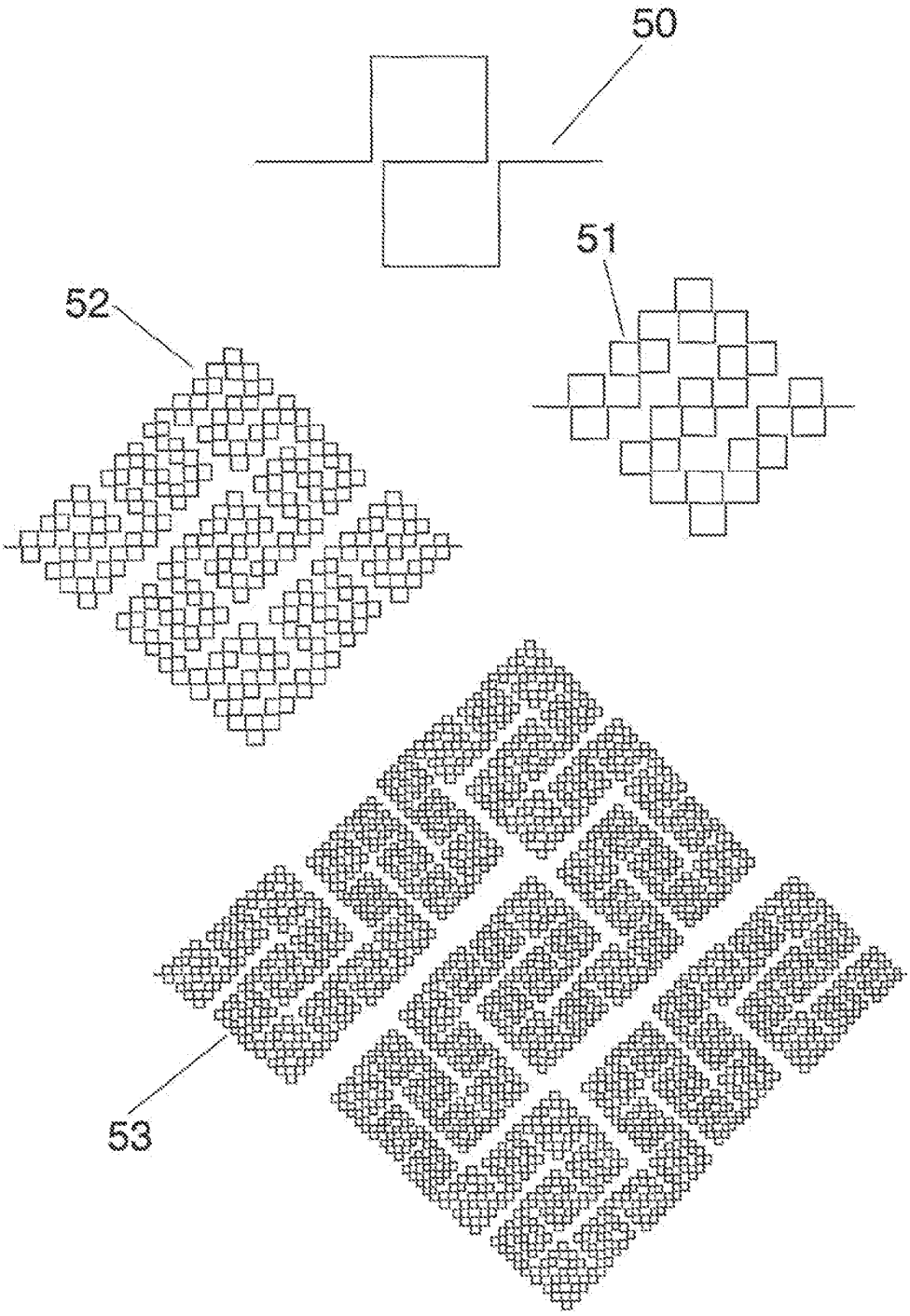


FIG. 19

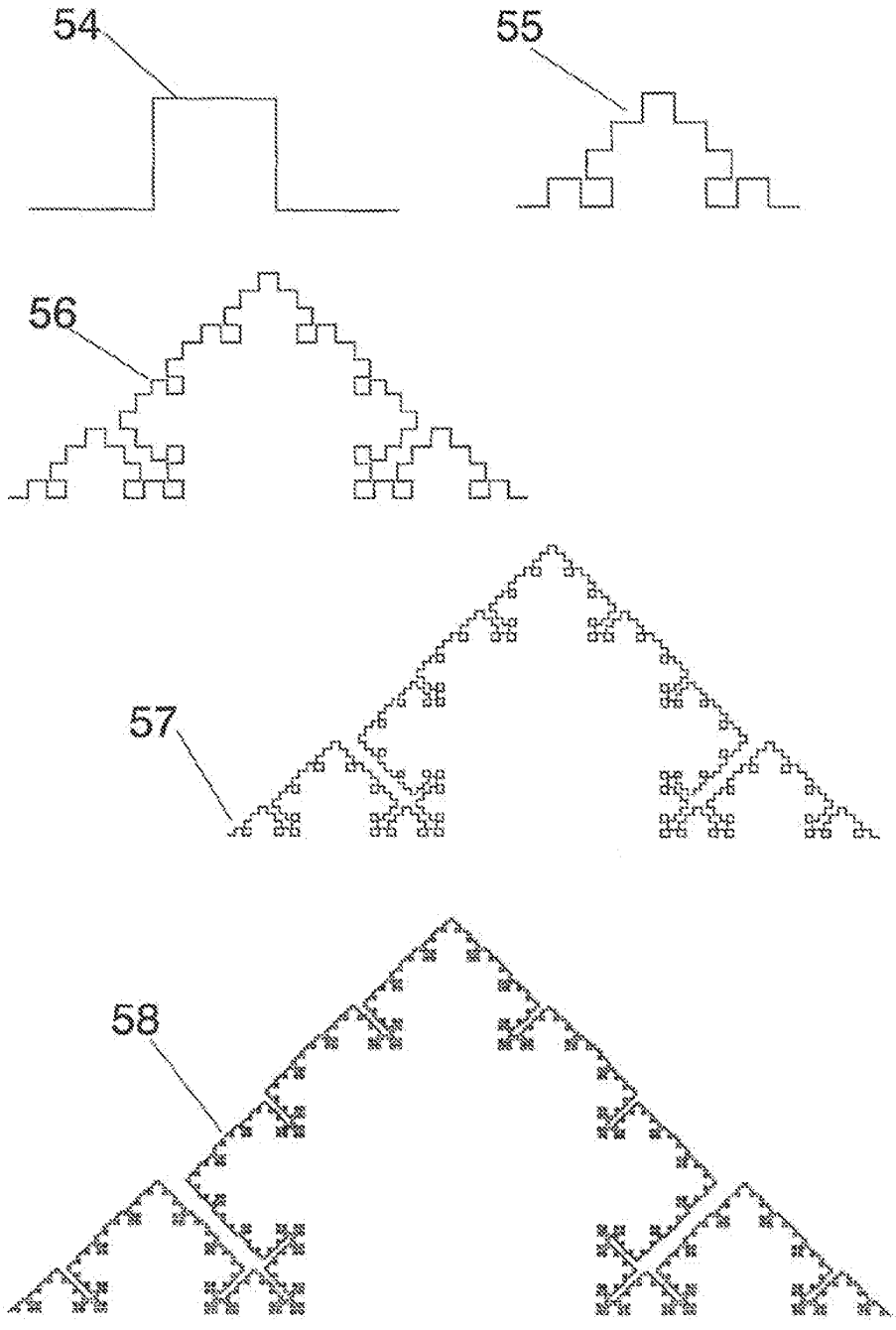


FIG. 20

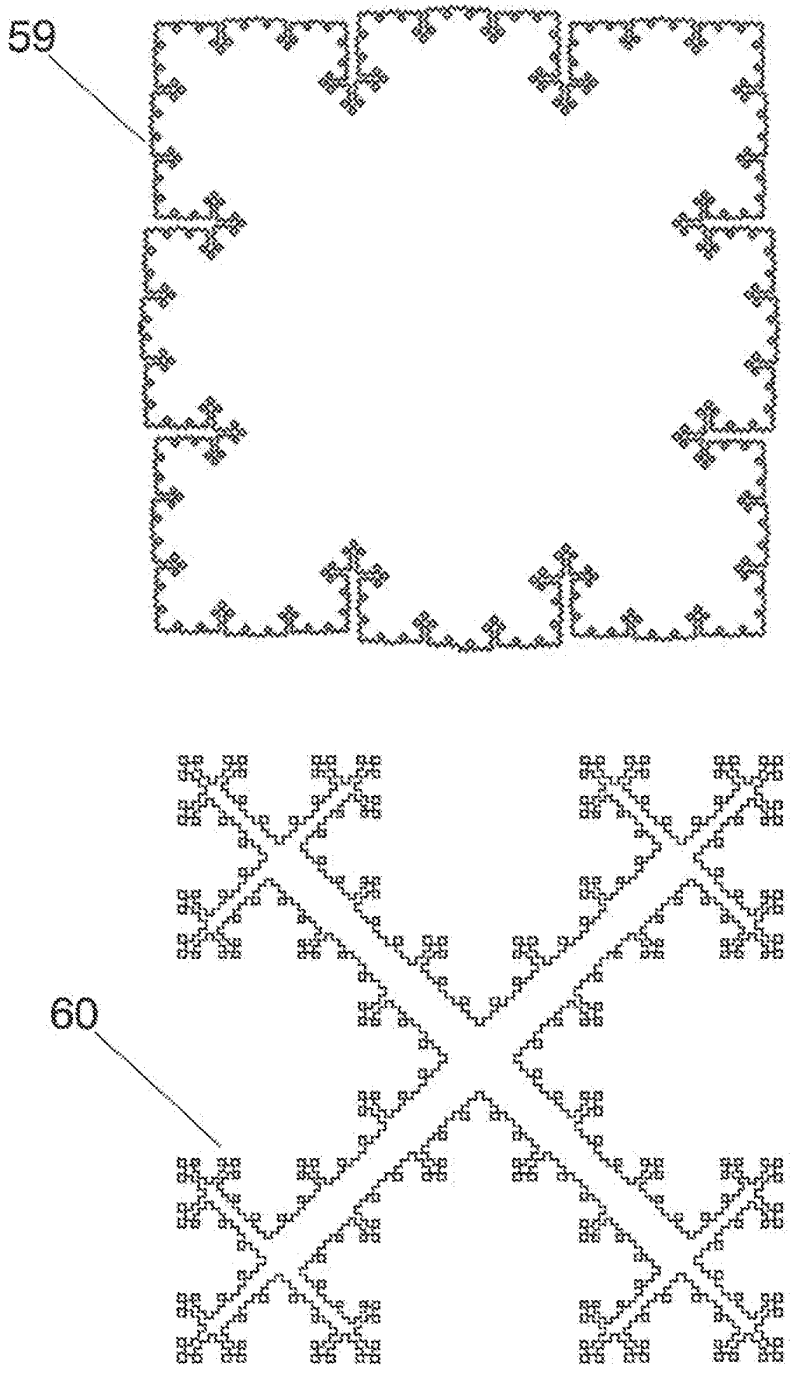


FIG. 21

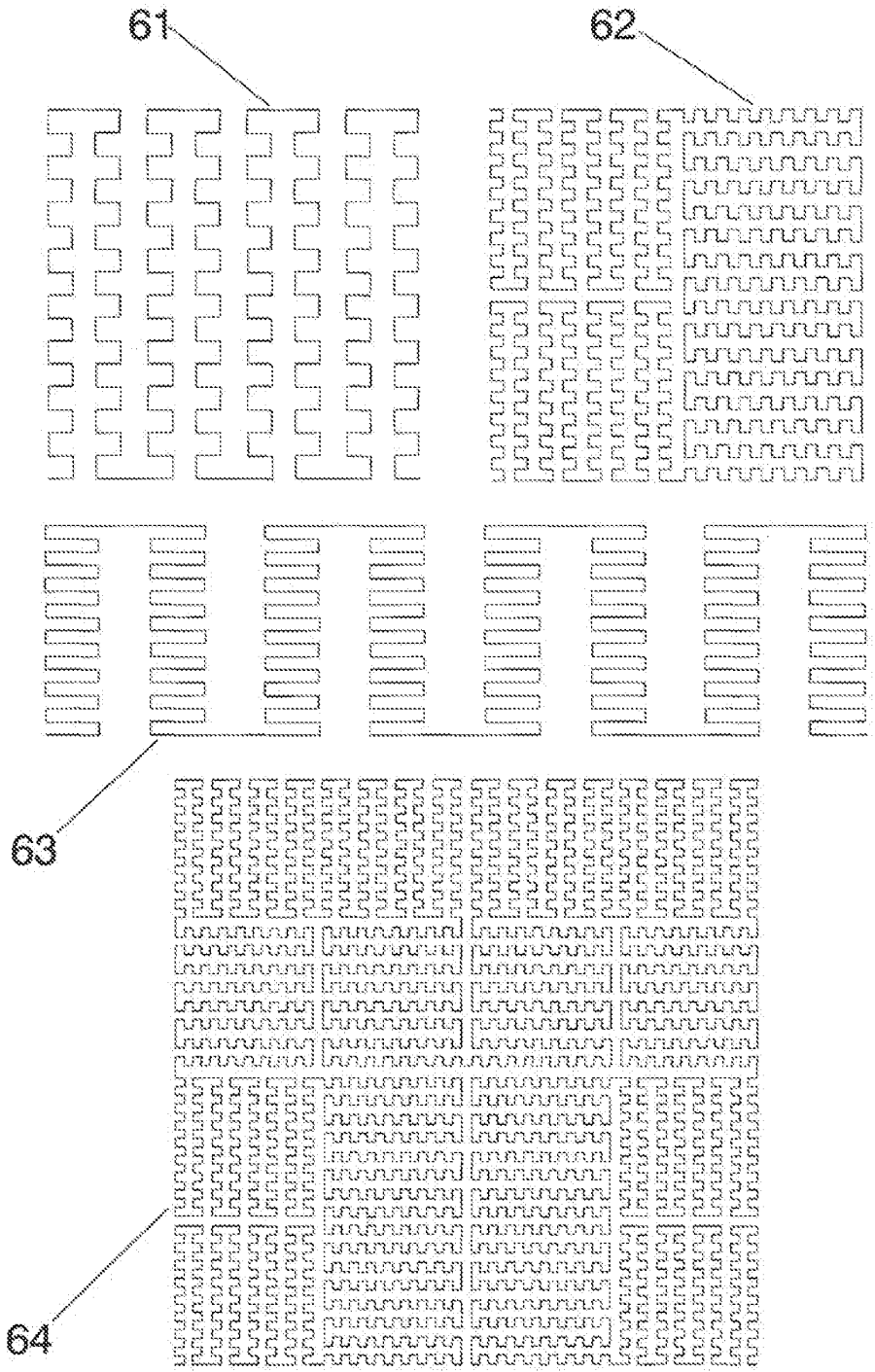


FIG. 22

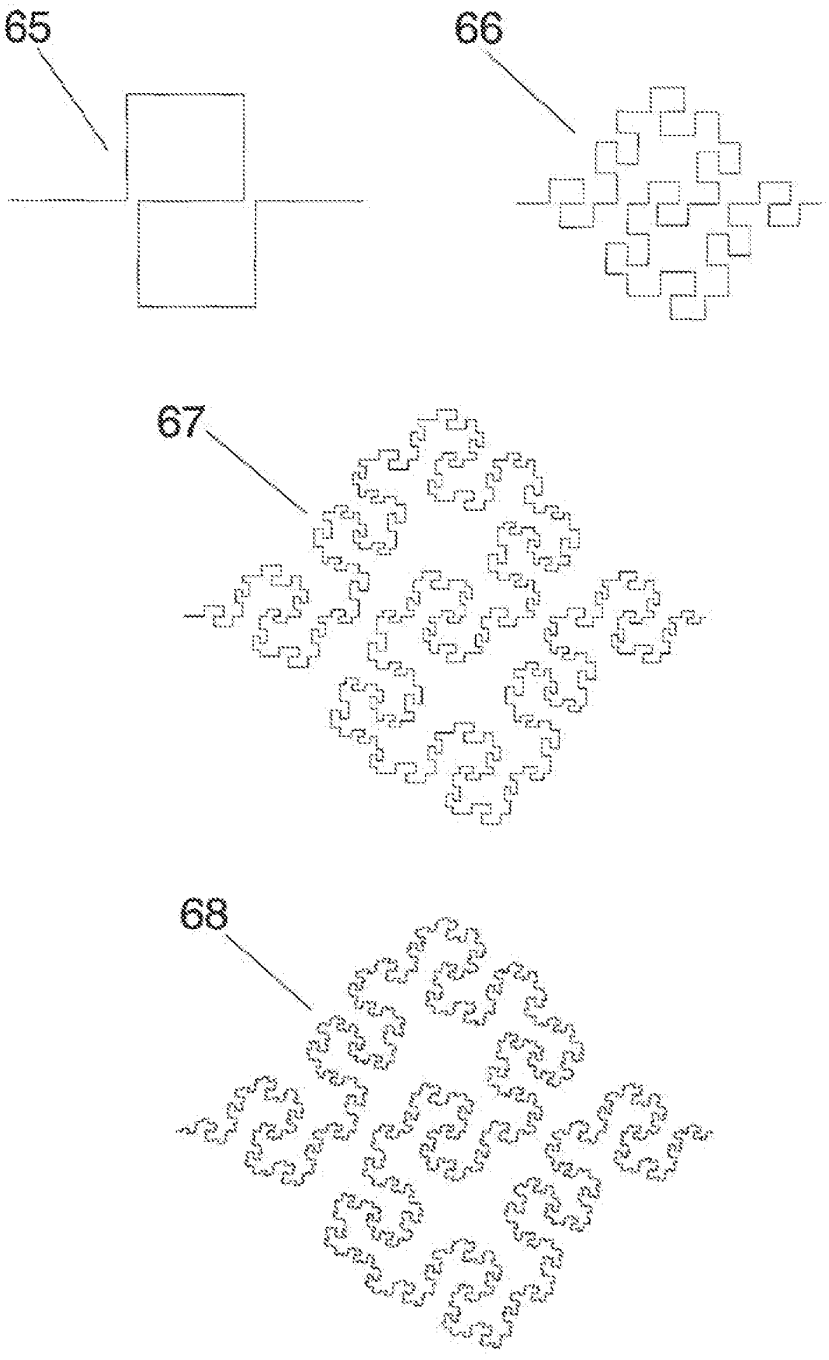


FIG. 23

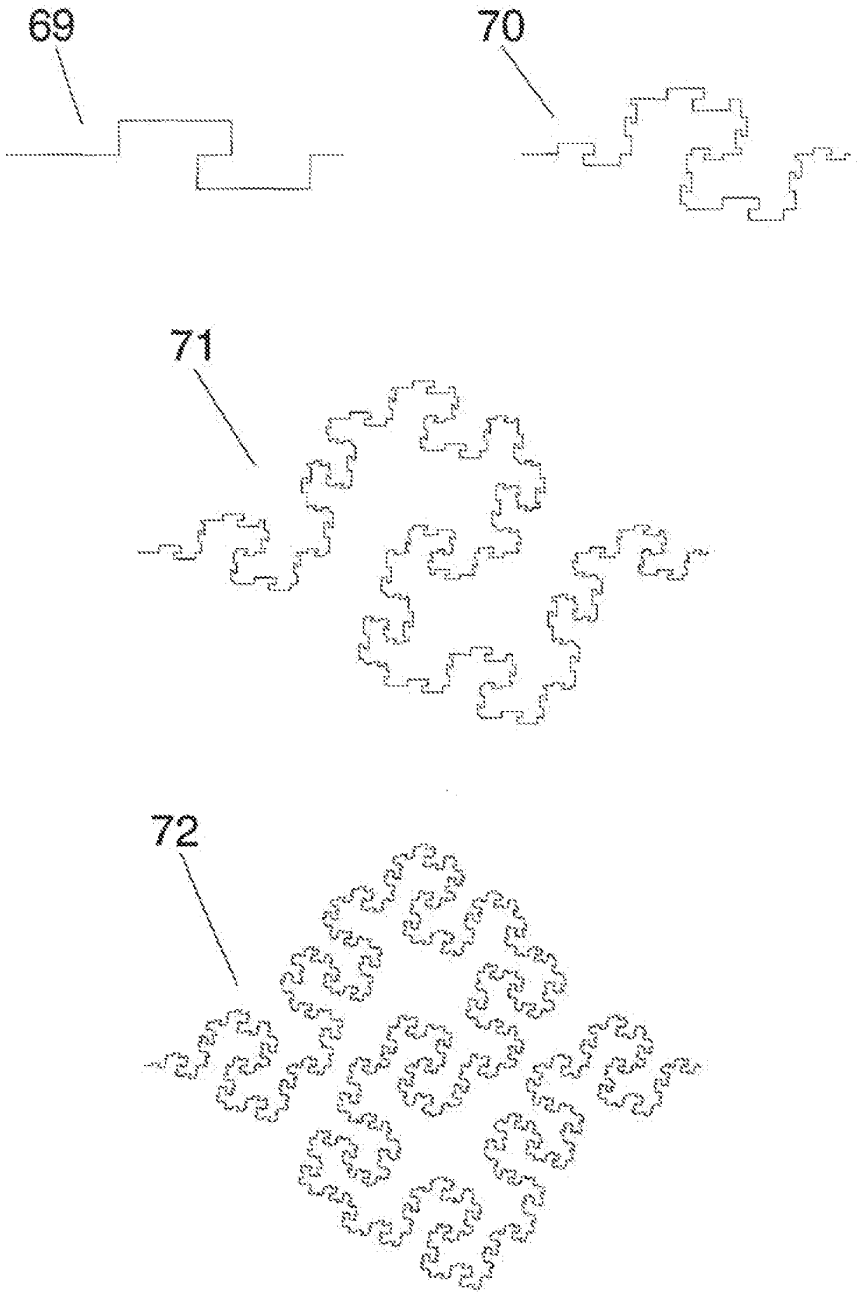


FIG. 24

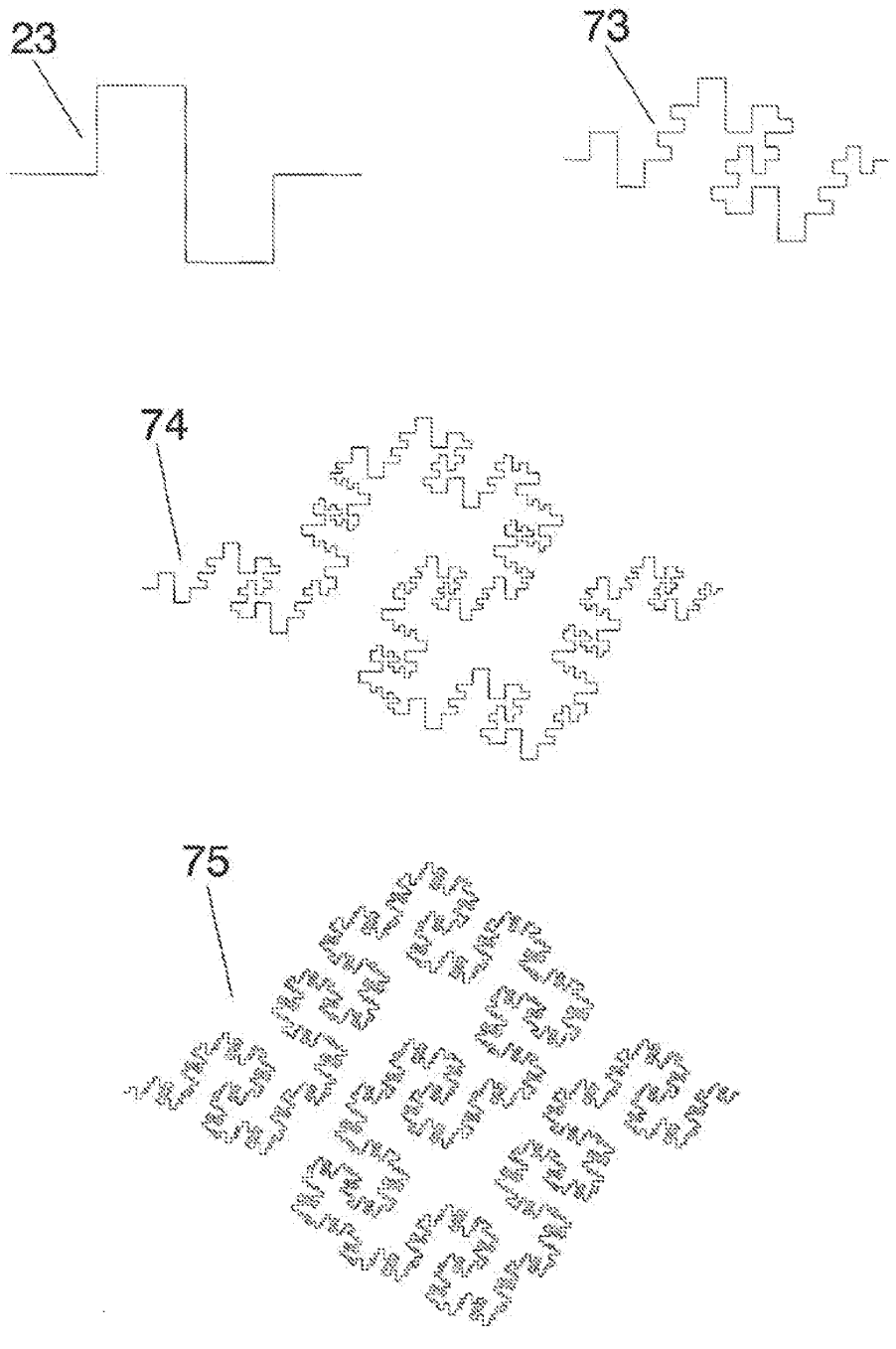


FIG. 25

INTERNATIONAL SEARCH REPORT

Int. application No
PCT/EP 00/00411

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q1/36

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01Q

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 97 06578 A (FRACTAL ANTENNA SYSTEMS INC ;COHEN NATHAN (US)) 20 February 1997 (1997-02-20) abstract	1-16
X	WO 99 27608 A (COHEN NATHAN) 3 June 1999 (1999-06-03) claims 1-11; figure 2A	1-16
X	US 4 843 468 A (DREWERY JOHN O) 27 June 1989 (1989-06-27) abstract	1-16
X	EP 0 969 375 A (SUN MICROSYSTEMS INC) 5 January 2000 (2000-01-05) abstract	1-16

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[X] Further documents are listed in the continuation of box C. [X] Patent family members are listed in annex.

* Special categories of cited documents :

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

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search	Date of mailing of the international search report
7 November 2000	14/11/2000

Name and mailing address of the ISA	Authorized officer
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Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP 00/00411

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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CLAIMS

[Claim(s)]
[Claim 1]
The 1st antenna provided with a shorting part which connects a ground conductor plate, the 1st radiation conductor plate that separates this ground conductor plate and a certain interval, and is countered and arranged, and this 1st radiation conductor plate and said ground conductor plate, and the 1st feed part for exciting said 1st radiation conductor plate,
The 2nd antenna provided with the 2nd radiation conductor plate that is formed between said 1st feed part and said shorting part, and has the 2nd feed part
An antenna which ****.
[Claim 2]
The 1st antenna provided with a shorting part which connects a ground conductor plate, the 1st radiation conductor plate that separates this ground conductor plate and a certain interval, and is countered and arranged, and this 1st radiation conductor plate and said ground conductor plate, and the 1st feed part for exciting said 1st radiation conductor plate,
The 2nd antenna provided with the 2nd radiation conductor plate that is formed in a field of the neighborhood containing an imaginary line which connects said 1st feed part and said shorting part, and has the 2nd feed part
An antenna which ****.
[Claim 3]
The antenna according to claim 1 or 2, wherein it cuts to said 1st radiation conductor, a chip field is formed and said at least a part of 2nd radiation conductor has entered in said end chip field.
[Claim 4]
While only distance beyond abbreviated 1/6 of a periphery of said 1st radiation conductor plate detaches and arranges said 1st feed part and said shorting part, said 1st antenna, An antenna given in any 1 paragraph to claims 1-3 having the 1st matching circuit that is connected to said 1st feed part and adjusts impedance of said 1st antenna.
[Claim 5]
While arranging said 1st feed part and said shorting part so that said 1st antenna may not resonate in a using frequency belt, An antenna given in any 1 paragraph to claims 1-4 having the 1st matching circuit that is connected to said 1st feed part and adjusts impedance of said 1st antenna.
[Claim 6]
An antenna given in any 1 paragraph to claims 1-5 having the 2nd matching circuit connected to said 2nd feed part.
[Claim 7]
The antenna comprising according to claim 6:
The 1st RF circuit connected to said 1st matching circuit.
The 2nd RF circuit connected to said 2nd matching circuit.

[Claim 8]
An antenna given in any 1 paragraph to claims 1-7, wherein it separates said ground conductor plate and a certain interval, and said 2nd radiation conductor counters and is arranged.

[Claim 9]
An antenna given in any 1 paragraph to claims 1-8 having arranged a field which forms said 1st radiation conductor plate, and a field which forms said 2nd radiation conductor plate in a position which crosses mutually.
[Claim 10]
An antenna given in any 1 paragraph to claims 1-9 having arranged in a position a position and a field which forms said 1st radiation conductor plate, and a field which forms said 2nd radiation conductor plate abbreviated-cross at right angles mutually.
[Claim 11]
An antenna given in any 1 paragraph to claims 1-10, wherein said 2nd radiation conductor has a bent part in part at least.
[Claim 12]
An antenna given in any 1 paragraph to claims 1-10, wherein at least a part is formed in L form, a zigzag configuration, or a meander form in said 2nd radiation conductor.
[Claim 13]
An antenna given in any 1 paragraph to claims 1-12, wherein said 1st radiation conductor plate and said 2nd radiation conductor plate are formed in a supporting board which supports these, and one.
[Claim 14]
An antenna given in any 1 paragraph to claims 1-13 having a using frequency belt with which said 1st antenna differs from said 2nd antenna.
[Claim 15]
Wireless radios which equipped any 1 paragraph to claims 1-14 with an antenna of a statement.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[Field of the Invention]
[0001]
This invention relates to the antenna for wireless radios which uses two or more frequency bands for details more about the wireless radios which used an antenna and it.
[Background of the Invention]
[0002]
There is what has radio art remarkable to development, and the wireless radios corresponding to the wireless system using two or more frequency bands are increasing in number in one wireless radios. In mobile wireless radios, such as a portable telephone, this tendency is strong especially. Drawing 9 is a figure showing the example of composition of the mobile wireless radios which have two antennas. It has the liquid crystal display 54 and the key base 55, and the 1st antenna 51 and 2nd antenna 52 that are two antennas are built in the case 53. It resonates in frequency which is different in the 1st antenna 51 and 2nd antenna 52, and is arranged in the state where it detached spatially so that combination between two antennas might become small. Therefore, even when performing simultaneously communication using the system which uses several different frequency bands, a mutual electric wave does not interfere each other so much, and comfortable communication can be performed.
[Description of the Invention]
[Problem(s) to be Solved by the Invention]
[0003]
As mentioned above, in order to secure the isolation between antennas in the wireless

radios carrying two or more antennas, the measures which detach and arrange the distance between antennas have been taken. However, in wireless radios in recent years, especially the cellular phone used by mobile communications, etc., the demand of a miniaturization is strong, and it is preferred to arrange an antenna to the space limited from such a viewpoint.

[0004]

An object of this invention is to provide the antenna with which a good isolation characteristic is acquired even if it arranges two or more antennas to the neighborhood, and the wireless radios using it.

[Means for Solving the Problem]

[0005]

The 1st radiation conductor plate that according to one viewpoint of this invention separates a ground conductor plate, this ground conductor plate, and a certain interval, and is countered and arranged, A shorting part which connects this 1st radiation conductor plate and said ground conductor plate, and the 1st feed part for exciting said 1st radiation conductor plate, An antenna which has the 2nd antenna provided with the 2nd radiation conductor plate that has the 2nd feed part provided between the 1st antenna of ********, and said 1st feed part and said shorting part is provided. A ground conductor plate and the 1st radiation conductor plate that separates this ground conductor plate and a certain interval, and is countered and arranged, A shorting part which connects this 1st radiation conductor plate and said ground conductor plate, and the 1st feed part for exciting said 1st radiation conductor plate, An antenna which has the 2nd antenna provided with the 2nd radiation conductor plate that is formed in a field of the neighborhood containing the 1st antenna of ******** and an imaginary line which connects said 1st feed part and said shorting part, and has the 2nd feed part is provided.

[0006]

It cuts to said 1st radiation conductor, a chip field is formed, and said at least a part of 2nd radiation conductor has entered in said end chip field. Said 1st antenna has the 1st matching circuit that is connected to said 1st feed part and adjusts impedance of said 1st antenna while only distance beyond abbreviated 1/6 of a periphery of said 1st radiation conductor plate detaches and arranges said 1st feed part and said shorting part. In a field of the neighborhood containing an imaginary line which connects the 1st feed part and said shorting part, field intensity of the 1st antenna becomes weak.

[0007]

Therefore, securing an isolation between both antennas so that communication of each 1st and 2nd antennas may not be affected by the above-mentioned arrangement, respectively, it becomes possible to approach and arrange and a miniaturization of an antenna is attained. When it applies, for example to wireless radios, a miniaturization of wireless radios is attained.

[0008]

Said 1st antenna has the 1st matching circuit that is connected to said 1st feed part and adjusts impedance of said 1st antenna while only distance beyond abbreviated 1/6 of a periphery of said 1st radiation conductor plate detaches and arranges said 1st feed part and said shorting part.

It enables this to secure widely a space which arranges said 2nd antenna.

[0009]

While arranging said 1st feed part and said shorting part so that said 1st antenna may not resonate with a using frequency belt, it has the 1st matching circuit that is connected to said 1st feed part and adjusts impedance of said 1st antenna. this optimizes said

matching circuit -- still better isolation characteristic **** -- things become possible.
[0010]
It has the 2nd matching circuit connected to said 2nd feed part. It has the 1st RF circuit connected to said 1st matching circuit, and the 2nd RF circuit connected to said 2nd matching circuit. Thereby, even if it is a case where said 1st antenna is resonating with two or more frequency bands, it becomes possible to acquire a good isolation characteristic in all the usage bands.
[0011]
A field which forms said 1st radiation conductor plate, and a field which forms said 2nd radiation conductor plate have been arranged in a position which crosses mutually. It is more preferred that a field which forms said 1st radiation conductor plate, and a field which forms said 2nd radiation conductor plate arrange in a position which abbreviated-intersects perpendicularly mutually. It becomes possible to acquire a thereby still better isolation characteristic.
[0012]
At least a part is formed in L form, a zigzag configuration, or a meander form in said 2nd radiation conductor. This becomes possible to miniaturize said 2nd antenna, and when distance of said 1st feeding point and said short circuit point is near, it becomes possible to arrange said 2nd antenna.
[0013]
Said 1st radiation conductor plate and said 2nd radiation conductor plate are formed in supporting boards, such as a flexible substrate, and one. Thereby, reduction of the number of parts and realization of a cost cut are also attained. Therefore, there is an advantage that wireless radios can be miniaturized.
[Effect of the Invention]
[0014]
As mentioned above, in the antenna of this invention, and the wireless radios using it, it becomes possible to arrange two or more antennas which have a high isolation in a small space.
[Best Mode of Carrying Out the Invention]
[0015]
Hereafter, an embodiment of the invention is described in detail with reference to drawings.
First, it explains, making a portable telephone into an example about the outline of the wireless radios using the antenna by an embodiment of the invention, and referring to drawings.
Drawing 1 is a perspective view showing the example of appearance composition of a portable telephone.
Drawing 2 is a functional block diagram showing the example of an internal configuration of the portable telephone shown in drawing 1.
Drawing 3 is a figure showing the example of an internal configuration of a portable telephone. Here, although a folded-up type portable telephone is made into an example and explained, this invention is applicable to the portable telephone of other gestalten, for example, the portable telephone of a straight-way type.
[0016]
As shown in drawing 1 (A) and (B), the portable telephone 10 by this embodiment has the 1st case (upper casing) 10a, the 2nd case (lower casing) 10b, and the hinge 21 for attaching these rotatable mutually, for example. LCD display 115 and the loudspeaker 123 are formed in the 1st case 10a side. On the other hand, the 1st antenna 111 and the 2nd antenna 112 which it is arranged in the 2nd case 10b, and are not illustrated, the

various manual operation buttons 122, and the microphone 124 and ** are provided in the 2nd case 10b side. It is common to the rear-face side of the portable telephone 10 that the camera 113a, the light 113b used also as lighting at the time of camera use, and ** are provided.

[0017]

As shown in drawing 2, to the portable telephone 10 by this embodiment. It is provided by the control section 231 which controls the whole and by this control section 231. The storage memory 232, the indicator 115, the loudspeaker 114, and the microphone 124, Control related without the 1st wireless section 238a and the 2nd wireless section 238b corresponding to the key input section 122, the voice output part 123, the camera 113a and the light 113b, the 1st antenna 111 and the 2nd antenna 112, and each antenna 111 and 112 is performed.

[0018]

As shown in drawing 3 (A) and (B), the portable telephone 10 by this embodiment, The 1st circuit component 15a that is the 1st circuit component 15a arranged in the 1st case (upper casing) 10a, has the wiring layer and circuit element which were provided between the substrate and substrate of several layers, and has conductivity as a whole, It is the 2nd circuit component 15b arranged in the 2nd case 10b, and has the 2nd circuit component 15b that has the wiring layer and circuit element which were similarly provided between the substrate and substrate of several layers, and has conductivity as a whole. Between the 1st case (upper casing) 10a and the 2nd case 10b, the hinge region 21 which connects them pivotable is formed. For example, near the hinge region 21, it is connected to the 2nd circuit component 15b, for example, and the 1st antenna 111 and 2nd antenna 112 that are mentioned later are formed.

[0019]

Next, it explains, referring to drawings for the details of the antenna by a 1st embodiment of this invention. Drawing 4 is a figure showing the example of composition of the antenna by a 1st embodiment of this invention applicable to above-mentioned wireless radios, for example. As shown in drawing 4, the 1st antenna 111 among the antennas by this embodiment, The 1st radiation conductor 11 that is arranged at the position which counters the plate-like earth conductor (ground conductor plate) 16 and this earth conductor 16, for example, consists of copper foil, It has the 1st feed part 13 provided in the earth conductor 16 in the shorting part 14 which short-circuits the earth conductor 16 and the 1st radiation conductor 11, and the position which only the distance d in the field inboard of the plate-like earth conductor 16 separated from the shorting part 14. It is common that either serves as the earth conductor 16 at least of the 1st or 2nd circuit component 15a and 15b. In the example shown in drawing 4, the 2nd circuit component 15b shown in drawing 3 serves as the earth conductor 16.

[0020]

As for the distance d between the 1st feed part 13 of the 1st antenna 111, and the shorting part 14, it is preferred that it is 1/6 or more to the length (periphery overall length) of the periphery of the 1st radiation conductor 11. The 1st feed part 13 passes along the matching circuit currently formed in the earth conductor 16, and is connected to the 1st RF circuit (refer to drawing 5). It cuts in the 1st radiation conductor 11 so that a concave field may be formed, and the chip part is formed in it.

[0021]

The 2nd antenna 112 As common, for example the plate-like earth conductor 16 as the 1st antenna 111, It has the 2nd radiation conductor 12 that is formed in a position which is arranged at the position which counters the earth conductor 16, and is different in the 1st radiation conductor 11, for example, consists of copper foil, passes along the 2nd

matching circuit currently formed on the earth conductor 16 of the 2nd feed part 15, and is connected to the 2nd RF circuit (refer to drawing 5). The 2nd radiation conductor 12 is formed in the field of the neighborhood containing the imaginary line which connects the 1st feed part 13 and shorting part 14. It is preferred that the 2nd feed part 15 is also arranged to the above-mentioned neighborhood field.

[0022]

More specifically it is arranged in the above-mentioned end chip field of the 2nd radiation conductor 12 and the 1st radiation conductor 11 between the 1st feed part 13 and the shorting part 14, and is, and the 2nd feed part is provided on the imaginary line which connects the 1st feed part 13 and shorting part 14, for example. Although the graphic display is omitted for details, The feed parts 13 and 15 and the shorting part 14, Springs, such as SPC (SpringConnector), are being fixed to the land provided on the 1st [which serves as the earth conductor 16 formed in the 1st or 2nd case 10a and 10b], or 2nd circuit board 15a and 15b (drawing 3) by soldering, The tip of the feed parts 13 and 15 and the shorting part 14 is made to contact a radiation conductor, and electric power is supplied, or it is grounded in the ground of the earth conductor 16. The member shown with the numerals 17 is a tabular member which consists of a flexible substrate (dielectric) which carries the 1st radiation conductor 11 or 2nd radiation conductor 12. This tabular member is mentioned later. A shorting part may be independently provided also in the 2nd radiation conductor.

[0023]

Drawing 5 is a figure showing the example of composition of the matching circuit which resembles the 1st antenna 111 and the 2nd antenna 112, and is connected, respectively. In drawing 5, although the 1st matching circuit 22 connected with the 1st antenna 111 at it is shown in the example, since the 2nd matching circuit connected with the 2nd antenna 112 at it is constituted similarly, the graphic display is omitted. Hereafter, it explains by making the 1st antenna 111 into an example, also referring to drawing 4.

[0024]

In the 1st antenna 111, it is connected to the matching circuit 22 (drawing 5) on the earth conductor 16 through the spring provided in the 1st feed part 13 from the radiation conductor 11. The resonance frequency of the 1st radiation conductor 11 in the state where the matching circuit 22 is not connected, In desired using frequency, it does not resonate, but by connecting with the matching circuit 22, it adjusts so that the efficiency of an antenna may become large in two frequency bands of two or more desired frequency, for example, 800 MHz bands and 1700 - 1900 MHz band. The 1st or 2nd matching circuit 22 is constituted as follows, for example. Namely, it is connected to the radiation conductor 11 and grounding part GNDof ** 1st 1, and the 1st inductor L1 is formed, The 1st capacitor C1 is formed in the wiring which branched from between the radiation conductor 11 and the 1st inductor, and as for wiring, while branching at the point is connected to grounding part GNDof ** 2nd 2 via the 2nd capacitor C2. Wiring of branched another side is connected to the 1st or 2nd RF circuit via the 2nd inductor L2. A matching circuit section may be formed only in a jumper and may be formed only with lines, such as a micro stripe and a TORIPU rate. On the other hand, the 2nd antenna 112 has the high frequency of the ISM band (2.4GHz bandwidth) etc. which are used by Bluetooth etc., for example, and its antenna with which element duration is short and ends is preferred.

[0025]

The field intensity from the 1st radiation conductor 11 in the 1st antenna 111, Since it is in the tendency which becomes the weakest between the 1st feed part 13 and the

shorting part 14, By arranging the 2nd radiation conductor 12 in the 2nd antenna 112 to the slitting field formed between the 1st feed part 13 and the shorting part 14 containing the above-mentioned imaginary line, The 2nd communications system with which the 1st communications system containing the 1st antenna 111 differs from the 1st communications system containing the 2nd antenna 112 becomes possible [acquiring a good isolation characteristic which does not have an adverse effect on a mutual communications system]. Therefore, since the two antennas 111 and 112 can be arranged by space-saving, the miniaturization of wireless radios is attained.

[0026]

Although the above-mentioned example explained the case where the 1st antenna 111 had two or more using frequency belts, it is applicable also to the case where it is used with a single frequency band. In drawing 4, while the 2nd radiation conductor 12 of the 2nd antenna 112 is formed in slitting of the 1st radiation conductor 11 of the 1st antenna 111, Although the example to which the 2nd feed part 15 of the 2nd radiation conductor 12 is located on the straight line which connects the 1st feed part 13 and shorting part 14 of the radiation conductor 11 was explained, Although such physical relationship is maintained fundamentally, the 2nd feed part 15 may be formed in the position [straight line] shifted for a while, and the 2nd radiation conductor 12 may also separate from a few out of slitting of the 1st radiation conductor 11. What is necessary is just to make it arranged at the position from which it separated for a while in the direction which intersects this straight line from the straight line which connects the feed part 13 and the shorting part 14, when there is no slitting in the 1st radiation conductor 11. Reduction of the number of parts and the realization of a cost cut of the 1st radial plate 11 and the 2nd radial plate 12 are also attained by creating using the flexible substrate of one sheet.

[0027]

Next, it explains, referring to drawings for the antenna by an embodiment of the invention. Drawing 6 is a figure showing the antenna by a 2nd embodiment of this invention carried in wireless radios. The 2nd antenna 132 changes arrangement of the 2nd radiation conductor 12 of the 2nd antenna 112 shown in above-mentioned Embodiment 1 among the 1st antenna 131 and the 2nd antenna 132 which are shown in drawing 6. Namely, the 1st antenna 131 among the 1st and 2nd antennas 131 and 132 by this embodiment, The plate-like earth conductor 36 and the 1st radiation conductor 31 arranged at the position which counters this earth conductor 36, It has the 1st feed part 33 provided in the earth conductor 36 in the shorting part 34 which short-circuits the earth conductor 36 and the 1st radiation conductor 31, and the position which only the distance d in the field inboard of the plate-like earth conductor 36 separated from the shorting part 34. One with preferred it being 1/6 or more to the length (periphery overall length) of the periphery of the 1st radiation conductor 31 of the distance d between the 1st feed part 33 and the shorting part 34 is the same as that of the antenna by a 1st embodiment. The 1st feed part 33 passes along the matching circuit currently formed in the earth conductor 36 as which the circuit component serves, for example, and is connected to the 1st RF circuit (refer to drawing 5).

[0028]

The 2nd radiation conductor 32 in the 2nd antenna 132 is arranged at the bottom of the case of a portable telephone, for example. On the other hand, the 1st radiation conductor 31 is arranged over the back of a case, and the field which forms these two radiation conductors 31 and 32 forms the field which crosses mutually, and forms the field which abbreviated-intersects perpendicularly by a diagram. The 2nd radiation conductor 32 passes along the 2nd matching circuit currently formed on the earth conductor 36, and is connected to the 2nd RF circuit by the 2nd feed part 35 (refer to drawing 5). The 2nd

feed part 35 is arranged at the slitting portion of the 1st radiation conductor 31 between the 1st feed part 33 and the shorting part 34, for example. The 1st page in contact with the earth conductor 36, and the 2nd page (after-mentioned) that continues with this 1st page and rises perpendicularly from the earth conductor 36, setting in a certain height following this 2nd page -- the earth conductor 36 -- abbreviated -- the flexible substrate 37 (the flexible substrate 17 which can set a 1st embodiment -- the same) which has the 3rd page (after-mentioned) that forms a parallel field, and is formed with a dielectric is formed. The 2nd radiation conductor 32 is put on the 2nd page, and the 1st radiation conductor 31 is put on the 3rd page.

[0029]

Thus, while being able to detach only the value of a request of the distance between the radiation conductors 31 and 32 by arranging the 1st radiation conductor 31 of the 1st antenna 131, and the 2nd radiation conductor 32 of the 2nd antenna 132 to the field which abbreviated-intersects perpendicularly, Since the size of the field where each of the radiation conductors 31 and 32 counters mutually becomes narrow, the field intensity between the 1st radiation conductor 31 and the 2nd radiation conductor 32 becomes weaker. Therefore, a much more good isolation characteristic can be acquired rather than being able to set between the 1st antenna 131 and the 2nd antenna 132.

[0030]

It may have the physical relationship which separated only from a few from the position shown in drawing 6 as the physical relationship between the 2nd feed part 35, and the 1st feed part 33 and the shorting part 34 was explained also in a 1st embodiment.

[0031]

Drawing 7 is a figure showing the structure of the antenna before an assembly. As shown in drawing 7, the flexible substrate 37, field contact is carried out at the earth conductor 36 (drawing 6) on the basis of the clinch lines DL1 and DL2 at the time of two inclusion -- with S1 the 1st page. It has S2 and the 3rd page that the 2nd page is incorporated to S2 the 2nd page, is vertical to return line DL2 occasionally, and has been arranged in parallel with the earth conductor 36 which incorporates the 1st page to S1 and rises from return line DL1 vertically occasionally. The 1st feed part 31 of the 1st antenna 131, and the 1st page of the 2nd feed part 35 and shorting part 34 of the 2nd antenna 132 are arranged S1. The 2nd page of the terminal area which are a part of 2nd radiation conductor 32 and 1st radiation conductor 31 is stationed S2. The 3rd page of the 1st radiation conductor 31 formed via the terminal area is arranged S3. As shown in drawing 7, the flexible substrate 37, the 1st radiation conductor 31, and the 2nd radiation conductor 32 are formed in one. Therefore, the process at the time of manufacture and inclusion becomes easy.

[0032]

Next, it explains, referring to drawings for the antenna by a 3rd embodiment of this invention. Drawing 8 is a figure showing the example of 1 composition of the antenna by this embodiment. The 1st and 2nd antennas 141 and 142 shown in drawing 8 have the almost same arrangement as the 1st and 2nd antennas 131 and 132 (drawing 6) by a 2nd above-mentioned embodiment, attach the numerals which added 10 to the numerals in drawing 6 about the same composition, and omit the explanation. The feature of the antennas 141 and 142 by this embodiment is the point that the shape of the 2nd radiation conductor 42 of the 2nd antenna 142 has become meander-like, as shown in drawing 7. Since the 2nd radiation conductor 42 is formed with the meander line, when the distance between the 1st feed part 43 of the 1st antenna 141 and the shorting part 44 is not so much separated, it becomes possible to arrange the 2nd radiation conductor 42 by the desired length.

[0033]
If the shape of the 2nd radiation conductor 42 is shape which has bent parts, such as the shape of JIGUZAKU, and is the shape which shortened an occupation area or distance with a longer occupied area to length, it will not be limited to the above-mentioned shape. As explained above, according to the antenna by this embodiment, and the portable telephone using it. For example, by arranging the 2nd radiation conductor and feed part of an antenna between the feed part of the 1st antenna, and a shorting part, it becomes possible to arrange two antennas which have a high isolation in a small space.
[0034]
In this embodiment, although the antenna which makes a portable telephone an example and is used for it was explained, it is possible to use for information terminals, such as other wireless radios, for example, PDA, PC, etc., and various electronic equipment which has a communication function.
[Industrial applicability]
[0035]
This invention is available at the antenna for wireless radios. The antenna of this invention is used and ** small wireless radios can be manufactured.
[Brief Description of the Drawings]
[0036]
[Drawing 1]Drawing 1 (A) and (B) is a perspective view showing the example of appearance composition of the portable telephone by an embodiment of the invention.
[Drawing 2]It is a functional block diagram showing the example of an internal configuration of the portable telephone shown in drawing 1.
[Drawing 3]Drawing 3 (A) and (B) is a figure showing the example of an internal configuration of a portable telephone.
[Drawing 4]It is a figure showing the example of composition of the antenna by a 1st embodiment of this invention.
[Drawing 5]It is a figure showing the example of 1 composition of the matching circuit linked to the antenna by this embodiment.
[Drawing 6]It is a figure showing the example of composition of the antenna by a 2nd embodiment of this invention.
[Drawing 7]The flexible substrate shown in drawing 6 and a radiation conductor are the figures showing the composition before the really molded assembly.
[Drawing 8]It is a figure showing the example of composition of the antenna by a 3rd embodiment of this invention.
[Drawing 9]Drawing 9 (A) and (B) is a figure showing the antenna carried in the conventional wireless radios.
[Description of Notations]
[0037]
10 -- A portable telephone (wireless radios), 11, 31, 41 -- The 1st radiation conductor, 12, 32, and 42 -- the -- The Ante radiation conductor of two, and 13, 33 and 43 -- the 1st feed part, and 14, 34 and 44 -- a shorting part, and 15, 35 and 45 -- the 2nd feed part, and 16, 36 and 46 -- an earth conductor (ground conductor plate) and 22 -- a matching circuit section and 51 -- the 1st antenna and 52 -- the 2nd antenna and 53 -- a case 54 [-- The 2nd antenna.] -- A liquid crystal display, 55 -- An operation key, 111, 131, 141 -- The 1st antenna, 112, 132, 142

(19)日本国特許庁(JP)　(12)公開特許公報(A)　(11)特許出願公開番号
特開2005-341313
(P2005-341313A)
(43)公開日　平成17年12月8日(2005.12.8)

(51)Int.Cl.[7]	F I		テーマコード（参考）
H01Q 13/08	H01Q 13/08		5J045
H01Q 1/24	H01Q 1/24	Z	5J046
H01Q 1/38	H01Q 1/38		5J047

審査請求 未請求　請求項の数 15　OL　（全 10 頁）

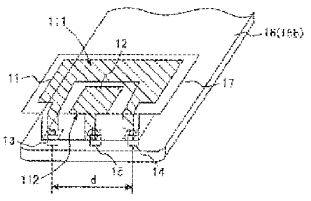
(21)出願番号　特願2004-158270 (P2004-158270)
(22)出願日　平成16年5月27日 (2004.5.27)

(71)出願人　000005049
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シャープ株式会社内

Ｆターム(参考)　5J045 AA03 AB05 BA01 DA09 EA07
LA04 NA03 NA04
5J046 AA02 AA07 AA12 AB06 AB11
PA07
5J047 AA02 AA07 AA12 AB06 AB11
FD01 FD02

(54)【発明の名称】アンテナおよびそれを用いた無線通信機

(57)【要約】　（修正有）
【課題】２つの独立したアンテナを近接して配置した場合においても、両アンテナ間において高いアイソレーションをもつ無線通信機を提供する。
【解決手段】第１のアンテナ１１１は、平板状の地導体１６と、第１の放射導体１１と、地導体１６と第１の放射導体１１とを短絡する短絡部１４と、短絡部１４から平板状の地導体１６の面内方向にある距離ｄだけ離れた位置に設けられた第１の給電部１３と、を有している。第１の給電部１３は、整合回路を通り、第１のＲＦ回路に接続されている。第２のアンテナ１１２は、第１のアンテナと共通の平板状の地導体１６と、地導体１６に対向する位置に配置され第１の放射導体１１とは異なる位置に設けられた第２の放射導体１２とを有し、第２の給電部１５によって地導体１６上に形成されている第２の整合回路を通り、第２のＲＦ回路に接続されている。
【選択図】図４



【特許請求の範囲】
【請求項1】
接地導体板と、該接地導体板とある間隔を隔てて対向して配置される第１の放射導体板と、該第１の放射導体板と前記接地導体板とを接続する短絡部と、前記第１の放射導体板を励振させるための第１の給電部と、を備えた第１のアンテナと、
前記第１の給電部と前記短絡部との間に設けられ第２の給電部を有する第２の放射導体板と、を備えた第２のアンテナと
を有するアンテナ。
【請求項2】
接地導体板と、該接地導体板とある間隔を隔てて対向して配置される第１の放射導体板と、該第１の放射導体板と前記接地導体板とを接続する短絡部と、前記第１の放射導体板を励振させるための第１の給電部と、を備えた第１のアンテナと、
前記第１の給電部と前記短絡部を結ぶ仮想線を含む近傍の領域に設けられ第２の給電部を有する第２の放射導体板と、を備えた第２のアンテナと
を有するアンテナ。
【請求項3】
前記第１の放射導体に切り欠け領域が形成されており、前記第２の放射導体の少なくとも一部が前記切り欠け領域内に入り込んでいることを特徴とする請求項１又は２に記載のアンテナ。
【請求項4】
前記第１のアンテナは、前記第１の給電部と前記短絡部とを前記第１の放射導体板の外周の略１／６以上の距離だけ離して配置するとともに、前記第１の給電部に接続され前記第１のアンテナのインピーダンスを調整する第１の整合回路を有することを特徴とする請求項１から３までのいずれか１項に記載のアンテナ。
【請求項5】
前記第１のアンテナが使用周波数帯において共振しないよう前記第１の給電部と前記短絡部とを配置するとともに、前記第１の給電部に接続され前記第１のアンテナのインピーダンスを調整する第１の整合回路を有することを特徴とする請求項１から４までのいずれか１項に記載のアンテナ。
【請求項6】
前記第２の給電部に接続される第２の整合回路を有することを特徴とする請求項１から５までのいずれか１項に記載のアンテナ。
【請求項7】
前記第１の整合回路に接続される第１のＲＦ回路と、前記第２の整合回路に接続される第２のＲＦ回路と、を有することを特徴とする請求項６に記載のアンテナ。
【請求項8】
前記第２の放射導体が、前記接地導体板とある間隔を隔てて対向して配置されることを特徴とする請求項１から７までのいずれか１項に記載のアンテナ。
【請求項9】
前記第１の放射導体板を形成する面と前記第２の放射導体板を形成する面とを互いに交差する位置に配置したことを特徴とする請求項１から８までのいずれか１項に記載のアンテナ。
【請求項10】
前記第１の放射導体板を形成する面と前記第２の放射導体板を形成する面とが互いに略直交する位置に配置したことを特徴とする請求項１から９までのいずれか１項に記載のアンテナ。
【請求項11】
前記第２の放射導体は、少なくとも一部に曲がり部分を有することを特徴とする請求項１から１０までのいずれか１項に記載のアンテナ。

【請求項12】
前記第２の放射導体を、少なくとも一部が、Ｌ形、ジグザグ形またはメアンダ形に形成されていることを特徴とする請求項１から１０までのいずれか１項に記載のアンテナ。
【請求項13】
前記第１の放射導体板と前記第２の放射導体板とが、これらを支持する支持基板と一体に形成されていることを特徴とする請求項１から１２までのいずれか１項に記載のアンテナ。
【請求項14】
前記第１のアンテナと前記第２のアンテナとが異なる使用周波数帯を有することを特徴とする請求項１から１３までのいずれか１項に記載のアンテナ。
【請求項15】
請求項１から１４までのいずれか１項に記載のアンテナを備えた無線通信機。
【発明の詳細な説明】
【技術分野】
【0001】
本発明は、アンテナ及びそれを用いた無線通信機に関し、より詳細には、複数の周波数帯を使用する無線通信機用のアンテナに関する。
【背景技術】
【0002】
無線通信技術が発展には著しいものがあり、１つの無線通信機において複数の周波数帯を用いる無線システムに対応する無線通信機が多くなってきている。特に携帯電話機などの移動体無線通信機においてはこの傾向は強くなっている。図９は、２つのアンテナを有する移動体無線通信機の構成例を示す図である。液晶ディスプレイ５４とキー基板５５とを有しており、２つのアンテナである、第１のアンテナ５１と第２のアンテナ５２とは、筐体５３に内蔵されている。第１のアンテナ５１と第２のアンテナ５２とは異なる周波数において共振し、２つのアンテナ間の結合が小さくなるように空間的に離した状態で配置されている。そのため、複数の異なる周波数帯を使用するシステムを用いた通信を同時に行う場合でも、お互いの電波がそれほど干渉し合わず、快適な通信を行なうことができる。
【発明の開示】
【発明が解決しようとする課題】
【0003】
上記のように、複数アンテナを搭載した無線通信機においてアンテナ間のアイソレーションを確保するために、アンテナ間の距離を離して配置する対策が取られてきた。しかしながら、近年の無線通信機、特に移動体通信で使用される携帯電話などにおいては小型化の要求が強く、このような観点から限られたスペースにアンテナを配置することが好ましい。
【0004】
本発明は、複数のアンテナを近くに配置しても良好なアイソレーション特性が得られるアンテナ及びそれを用いた無線通信機を提供することを目的とする。
【課題を解決するための手段】
【0005】
本発明の一観点によれば、接地導体板と、該接地導体板とある間隔を隔てて対向して配置される第１の放射導体板と、該第１の放射導体板と前記接地導体板とを接続する短絡部と、前記第１の放射導体板を励振させるための第１の給電部と、を備えた第１のアンテナと、前記第１の給電部と前記短絡部との間に設けられた第２の給電部を有する第２の放射導体板と、を備えた第２のアンテナとを有するアンテナが提供される。また、接地導体板と、該接地導体板とある間隔を隔てて対向して配置される第１の放射導体板と、該第１の放射導体板と前記接地導体板とを接続する短絡部と、前記第１の放射導体板を励振させるための第１の給電部と、を備えた第１のアンテナと、前記第１の給電部と前記短絡部を結ぶ仮想線を含む近傍の領域に設けられ第２の給電部を有する第２の放射導体板と、を備え

た第２のアンテナとを有するアンテナが提供される。

【0006】

前記第１の放射導体に切り欠け領域が形成されており、前記第２の放射導体の少なくとも一部が前記切り欠け領域内に入り込んでいることを特徴とする。また、前記第１のアンテナは、前記第１の給電部と前記短絡部とを前記第１の放射導体板の外周の略１／６以上の距離だけ離して配置するとともに、前記第１の給電部に接続され前記第１のアンテナのインピーダンスを調整する第１の整合回路を有することを特徴とする。第１の給電部と前記短絡部を結ぶ仮想線を含む近傍の領域において第１のアンテナの電界強度が弱くなる。

【0007】

従って、上記配置により第１及び第２のそれぞれのアンテナの通信にそれぞれ影響を与えないように両アンテナ間のアイソレーションを確保しつつ、近接して配置することが可能となり、アンテナの小型化が可能になる。さらに、例えば無線通信機に適用した場合に、無線通信機の小型化が可能となる。

【0008】

前記第１のアンテナは、前記第１の給電部と前記短絡部とを前記第１の放射導体板の外周の略１／６以上の距離だけ離して配置するとともに、前記第１の給電部に接続され前記第１のアンテナのインピーダンスを調整する第１の整合回路を有することを特徴とする。これにより、前記第２のアンテナを配置するスペースを広く確保することが可能となる。

【0009】

前記第１のアンテナが使用周波数帯で共振しないように前記第１の給電部と前記短絡部とを配置するとともに、前記第１の給電部に接続され前記第１のアンテナのインピーダンスを調整する第１の整合回路を有することを特徴とする。これにより、前記整合回路を最適化することにより、さらに良好なアイソレーション特性得ることが可能となる。

【0010】

前記第２の給電部に接続される第２の整合回路を有することを特徴とする。前記第１の整合回路に接続される第１のＲＦ回路と、前記第２の整合回路に接続される第２のＲＦ回路と、を有することを特徴とする。これにより、前記第1のアンテナが複数の周波数帯で共振している場合であっても、すべての使用帯域において良好なアイソレーション特性を得ることが可能となる。

【0011】

前記第１の放射導体板を形成する面と前記第２の放射導体板を形成する面とを互いに交差する位置に配置したことを特徴とする。前記第１の放射導体板を形成する面と前記第２の放射導体板を形成する面とが互いに略直交する位置に配置するのがより好ましい。これにより、さらに良好なアイソレーション特性を得ることが可能となる。

【0012】

前記第２の放射導体を、少なくとも一部が、Ｌ形、ジグザグ形またはメアンダ形に形成されていることを特徴とする。これにより、前記第2のアンテナを小型化することが可能となり、前記第1の給電点と前記短絡点の距離が近い場合においても、前記第2のアンテナを配置することが可能となる。

【0013】

前記第１の放射導体板と、前記第２の放射導体板を例えばフレキシブル基板などの支持基板と一体に形成していることを特徴とする。これにより、部品数の削減、コストダウンの実現も可能となる。従って、無線通信機を小型化することができるという利点がある。

【発明の効果】

【0014】

以上のように、本発明のアンテナおよびそれを用いた無線通信機においては、小さいスペースで高いアイソレーションをもつ複数のアンテナを配置することが可能となる。

【発明を実施するための最良の形態】

【0015】

以下、本発明の実施の形態について、図面を参照して詳細に説明する。

まず、本発明の実施の形態によるアンテナを用いた無線通信機の概要について携帯電話機を例にして図面を参照しながら説明する。

図１は、携帯電話機の外観構成例を示す斜視図である。

図２は、図１に示す携帯電話機の内部構成例を示す機能ブロック図である。

図３は、携帯電話機の内部構成例を示す図である。ここでは、折り畳み型携帯電話機を例にして説明するが、他の形態の携帯電話機、例えばストレート型の携帯電話機にも本発明は適用可能である。

【0016】

図１（Ａ）、（Ｂ）に示すように、本実施の形態による携帯電話機１０は、例えば、第１の筐体（上筐体）１０ａと、第２の筐体（下筐体）１０ｂと、これらを互いに回動可能に取り付けるためのヒンジ２１と、を有している。さらに、第１の筐体１０ａ側にＬＣＤ表示部１１５と、スピーカ１２３とが設けられている。一方、第２の筐体１０ｂ側には、第２の筐体１０ｂ内に配置され図示しない第１のアンテナ１１１と第２のアンテナ１１２と、各種操作ボタン類１２２と、マイクロフォン１２４と、が設けられている。携帯電話機１０の裏面側には、カメラ１１３ａと、カメラ使用時の照明としても用いられるライト１１３ｂと、が設けられているのが一般的である。

【0017】

図２に示すように、本実施の形態による携帯電話機１０には、全体の制御を行う制御部２３１が設けられ、この制御部２３１により、記憶メモリ２３２と、表示部１１５と、スピーカ１１４と、マイク１２４と、キー入力部１２２と、音声出力部１２３と、カメラ１１３ａ及びライト１１３ｂと、第１のアンテナ１１１及び第２のアンテナ１１２と、それぞれのアンテナ１１１、１１２に対応する第１の無線部２３８ａ及び第２の無線部２３８ｂと、に関する制御が行われる。

【0018】

図３（Ａ）、（Ｂ）に示すように、本実施の形態による携帯電話機１０は、第１の筐体（上筐体）１０ａ内に配置されている第１の回路部材１５ａであって、数層の基板と基板間に設けられた配線層と回路素子とを有し、全体として導電性を有する第１の回路部材１５ａと、第２の筐体１０ｂ内に配置されている第２の回路部材１５ｂであって、同じく数層の基板と基板間に設けられた配線層と回路素子とを有し、全体として導電性を有する第２の回路部材１５ｂと、を有している。第１の筐体（上筐体）１０ａと第２の筐体１０ｂとの間には、それらを回転可能に接続するヒンジ部２１が設けられている。例えばヒンジ部２１の近傍には、例えば第２の回路部材１５ｂに接続され、後述する第１のアンテナ１１１及び第２のアンテナ１１２が設けられている。

【0019】

次に、本発明の第１の実施の形態によるアンテナの詳細について図面を参照しつつ説明を行う。図４は、例えば上述の無線通信機に適用可能な本発明の第１の実施の形態によるアンテナの構成例を示す図である。図４に示すように、本実施の形態によるアンテナのうち、第１のアンテナ１１１は、平板状の地導体（接地導体板）１６と、この地導体１６に対向する位置に配置され例えば銅箔からなる第１の放射導体１１と、地導体１６と第１の放射導体１１とを短絡する短絡部１４と、短絡部１４から平板状の地導体１６の面内方向にある距離ｄだけ離れた位置において地導体１６に設けられた第１の給電部１３と、を有している。第１又は第２の回路部材１５ａ、１５ｂの少なくともいずれかが、地導体１６を兼ねるのが一般的である。図４に示す例では、図３に示す第２の回路部材１５ｂが、地導体１６を兼ねている。

【0020】

第１のアンテナ１１１の第１の給電部１３と短絡部１４との間の距離ｄは、第１の放射導体１１の外周の長さ（外周全長）に対して１／６以上であるのが好ましい。第１の給電部１３は、地導体１６に形成されている整合回路を通り、第１のＲＦ回路に接続されている（図５参照）。第１の放射導体１１には、四領域を形成するように切り欠け部が形成されている。

【0021】
第２のアンテナ１１２は、例えば第１のアンテナ１１１と共通の平板状の地導体１６と、地導体１６に対向する位置に配置され第１の放射導体１１とは異なる位置に設けられ例えば銅箔からなる第２の放射導体１２とを有し、第２の給電部１５によって地導体１６上に形成されている第２の整合回路を通り、第２のＲＦ回路に接続されている（図５参照）。第２の放射導体１２は、第１の給電部１３と短絡部１４とを結ぶ仮想線を含むその近傍の領域に設けられている。第２の給電部１５も上記の近傍領域に配置されるのが好ましい。
【0022】
より具体的には、第２の放射導体１２と例えば、第１の給電部１３と短絡部１４との間の第１の放射導体１１の上記切り欠け領域内に配置されおり、第２の給電部は、例えば第１の給電部１３と短絡部１４とを結ぶ仮想線上に設けられている。尚、詳細は図示を省略しているが、給電部１３・１５、短絡部１４は、第１又は第２の筐体１０ａ・１０ｂ内に設けられた地導体１６を兼ねる第１又は第２の回路基板１５ａ・１５ｂ（図３）上に設けられたランドに例えばＳＰＣ（Ｓｐｒｉｎｇ　Ｃｏｎｎｅｃｔｏｒ）などのバネが半田付けにより固定されており、給電部１３・１５、短絡部１４の先端を放射導体に当接させて、給電し、或いは地導体１６のグランドに接地されている。符号１７で示す部材は、第１の放射導体１１又は第２の放射導体１２を載せるフレキシブル基板（誘電体）からなる板状部材である。この板状部材については後述する。尚、第２の放射導体にも別に短絡部を設けても良い。
【0023】
図５は、第１のアンテナ１１１と、第２のアンテナ１１２と、にそれぞれ接続される整合回路の構成例を示す図である。図５においては、第１のアンテナ１１１とそれに接続される第１の整合回路２２を例に示しているが、第２のアンテナ１１２とそれに接続する第２の整合回路も同様に構成されるため、図示を省略している。以下、図４も参照しつつ第１のアンテナ１１１を例にして説明を行なう。
【0024】
第１のアンテナ１１１において、放射導体１１から第１の給電部１３に設けられたバネを通って地導体１６上の整合回路２２（図５）に接続されている。整合回路２２が接続されていない状態での第１の放射導体１１の共振周波数は、所望の使用周波数では共振しておらず、整合回路２２に接続することにより、所望の複数の周波数、例えば、８００ＭＨｚ帯と１７００～１９００ＭＨｚ帯との２つの周波数帯においてアンテナの効率が大きくなるように調整する。第１又は第２の整合回路２２は、例えば、以下のように構成されている。すなわち、放射導体１１と第１の接地部ＧＮＤ１とに接続され第１のインダクタＬ１が設けられ、放射導体１１と第１のインダクタとの間から分岐された配線に第１のキャパシタＣ１が設けられ、その先で分岐された一方の配線は、第２のキャパシタＣ２を介して第２の接地部ＧＮＤ２に接続されている。分岐された他方の配線は、第２のインダクタＬ２を介して第１又は第２のＲＦ回路に接続されている。尚、整合回路部は、ジャンパーのみで形成されても良く、マイクロストリップやトリプレートなどのラインのみで形成されていてもよい。一方、第２のアンテナ１１２は、例えば、ブルートゥースなどで使用されているＩＳＭ帯（２．４ＧＨｚ帯）などの周波数が高く、エレメント長が短くてすむアンテナが好ましい。
【0025】
第１のアンテナ１１１における第１の放射導体１１からの電界強度は、第１の給電部１３と短絡部１４との間において最も弱くなる傾向にあるため、第２のアンテナ１１２における第２の放射導体１２を上記仮想線を含む第１の給電部１３と短絡部１４との間に形成された切り込み領域に配置することにより、第１のアンテナ１１１を含む第１の通信システムと第２のアンテナ１１２を含む第１の通信システムとが異なる第２の通信システムとが、お互いの通信システムに悪影響を及ぼさないような良好なアイソレーション特性を得ることが可能となる。従って、２つのアンテナ１１１、１１２を省スペースで配置するこ

とができるため、無線通信機の小型化が可能になる。

【0026】

また、上記の例では、第１のアンテナ１１１が複数の使用周波数帯を有する場合について説明をしたが、単一の周波数帯で使用する場合についても適用可能である。また、図４においては、第１のアンテナ１１１の第１の放射導体１１の切り込み内に第２のアンテナ１１２の第２の放射導体１２が設けられるとともに、第１の放射導体１１の給電部１３と短絡部１４とを結ぶ直線上に第２の放射導体１２の第２の給電部１５が位置している例について説明したが、これらの位置関係は基本的には維持されるものの、直線から少しずれた位置に第２の給電部１５が設けられていても良いし、第２の放射導体１２も第１の放射導体１１の切り込み内から少し外れていても良い。第１の放射導体１１に切り込みがない場合には、給電部１３と短絡部１４とを結ぶ直線からこの直線と交差する方向に少し外れた位置に配置されるようにすれば良い。また、第１の放射板１１、第２の放射板１２は、１枚のフレキシブル基板を用いて作成することにより、部品数の削減、コストダウンの実現も可能となる。

【0027】

次に、本発明の実施の形態によるアンテナについて図面を参照しつつ説明を行う。図６は、無線通信機に搭載された本発明の第２の実施の形態によるアンテナを示す図である。図６に示す第１のアンテナ１３１と第２のアンテナ１３２のうち第２のアンテナ１３２は、上述の実施の形態１に示す第２のアンテナ１１２の第２の放射導体１２の配置を変化させたものである。すなわち、本実施の形態による第１及び第２のアンテナ１３１、１３２のうち、第１のアンテナ１３１は、平板状の地導体３６と、この地導体３６に対向する位置に配置された第１の放射導体３１と、地導体３６と第１の放射導体３１とを短絡する短絡部３４と、短絡部３４から平板状の地導体３６の面内方向にある距離ｄだけ離れた位置において地導体３６に設けられた第１の給電部３３と、を有している。第１の給電部３３と短絡部３４との間の距離ｄは、第１の放射導体３１の外周の長さ（外周全長）に対して１／６以上であるのが好ましいのは第１の実施の形態によるアンテナと同様である。第１の給電部３３は、例えば回路部材が兼ねている地導体３６に形成されている整合回路を通り、第１のＲＦ回路に接続されている（図５参照）。

【0028】

第２のアンテナ１３２における第２の放射導体３２は、例えば、携帯電話機の筐体の底面に配置されている。一方、第１の放射導体３１は筐体の例えば背面に沿って配置されており、この２つの放射導体３１、３２を形成する面は互いに交差する面を形成しており、図では略直交する面を形成している。第２の放射導体３２は、第２の給電部３５によって地導体３６上に形成されている第２の整合回路を通り、第２のＲＦ回路に接続されている（図５参照）。第２の給電部３５は、例えば、第１の給電部３３と短絡部３４との間の第１の放射導体３１の切り込み部分に配置されている。また、地導体３６に接触する第１面と、この第１面と続き地導体３６から垂直方向に立ち上がる第２面（後述）と、この第２面に続きある高さにおいて地導体３６と略平行な面を形成する第３面（後述）とを有し誘電体により形成されるフレキシブル基板３７（第１の実施の形態のおけるフレキシブル基板１７と同様）が設けられている。第２面には第２の放射導体３２が、第３面には第１の放射導体３１が載せられている。

【0029】

このように、第１のアンテナ１３１の第１の放射導体３１と、第２のアンテナ１３２の第２の放射導体３２とを略直交する面に配置することにより、放射導体３１、３２間の距離を所望の値だけ離すことができるとともに、放射導体３１、３２のそれぞれが互いに対向する面の広さが狭くなるため、第１の放射導体３１と第２の放射導体３２との間の電界強度が弱まる。従って、第１のアンテナ１３１と第２のアンテナ１３２との間におけるより一層良好なアイソレーション特性を得ることができる。

【0030】

尚、第２の給電部３５と、第１の給電部３３及び短絡部３４の間の位置関係に関しては

、第１の実施の形態においても説明した通り、図６に示した位置から少しだけ外れた位置関係を有していても良い。

【0031】

図７は組み立て前のアンテナの構造を示す図である。図７に示すように、フレキシブル基板３７は、２つの組み込み時折り返し線ＤＬ１及びＤＬ２を基準にして、地導体３６（図６）に面接触する第１面Ｓ１と、第１面Ｓ１に対して組み込み時折り返し線ＤＬ１から垂直に立ち上がる第２面Ｓ２と、第２面Ｓ２に対して組み込み時折り返し線ＤＬ２と垂直であり地導体３６と平行に配置された第３面と、を有している。第１のアンテナ１３１の第１の給電部３１と、第２のアンテナ１３２の第２の給電部３５と短絡部３４とは、第１面Ｓ１に配置されている。第２の放射導体３２と第１の放射導体３１の一部である接続部とは第２面Ｓ２に配置されている。接続部を介して形成された第１の放射導体３１は第３面Ｓ３に配置されている。図７に示すようにフレキシブル基板３７と第１の放射導体３１と第２の放射導体３２とが一体に形成されている。従って、製造時及び組み込み時の工程が簡単になる。

【0032】

次に、本発明の第３の実施の形態によるアンテナについて図面を参照しつつ説明を行う。図８は、本実施の形態によるアンテナの一構成例を示す図である。図８に示す第１及び第２のアンテナ１４１、１４２は、上述の第２の実施の形態による第１及び第２のアンテナ１３１、１３２（図６）とほぼ同様の配置を有しており、同様の構成に関しては、図６における符号に１０を加算した符号を付してその説明を省略する。本実施の形態によるアンテナ１４１、１４２の特徴は、図７に示すように、第２のアンテナ１４２の第２の放射導体４２の形状がメアンダ状になっている点である。第２の放射導体４２はメアンダラインで形成してあるため、第１のアンテナ１４１の第１の給電部４３と短絡部４４との間の距離がそれほど離れていない場合においても第２の放射導体４２を所望の長さで配置することが可能となる。

【0033】

尚、第２の放射導体４２の形状は、ジグザク状など曲がり部分を有する形状であり、長さに対して占有面積又は占有領域の長い方の距離を短くした形状であれば、上記形状に限定されるものではない。以上に説明したように、本実施の形態によるアンテナおよびそれを用いた携帯電話機によれば、例えば第１のアンテナの給電部と短絡部との間に第２のアンテナの放射導体及び給電部を配置することにより、小さいスペースで高いアイソレーションをもつ２つのアンテナを配置することが可能となる。

【0034】

尚、本実施の形態においては、携帯電話機を例にしてそれに用いるアンテナについて説明したが、他の無線通信機、例えば、ＰＤＡやＰＣなどの情報端末や、通信機能を有する種々の電子機器に用いることが可能である。

【産業上の利用可能性】

【0035】

本発明は、無線通信機用のアンテナに利用可能である。また、本発明のアンテナを利用すれば小型無線通信機を製造することができる。

【図面の簡単な説明】

【0036】

【図1】図１（Ａ）、（Ｂ）は、本発明の実施の形態による携帯電話機の外観構成例を示す斜視図である。

【図2】図１に示す携帯電話機の内部構成例を示す機能ブロック図である。

【図3】図３（Ａ）、（Ｂ）は、携帯電話機の内部構成例を示す図である。

【図4】本発明の第１の実施の形態によるアンテナの構成例を示す図である。

【図5】本実施の形態によるアンテナに接続する整合回路の一構成例を示す図である。

【図6】本発明の第２の実施の形態によるアンテナの構成例を示す図である。

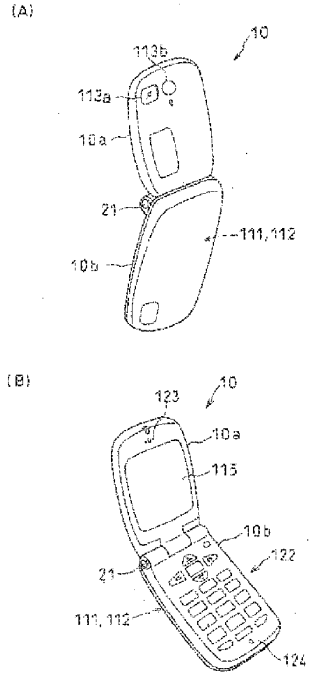
【図7】図６に示すフレキシブル基板と放射導体とが一体成型された組み立て前の構成を

示す図である。
【図8】本発明の第３の実施の形態によるアンテナの構成例を示す図である。
【図9】図９（Ａ）、（Ｂ）は、従来の無線通信機に搭載されたアンテナを示す図である

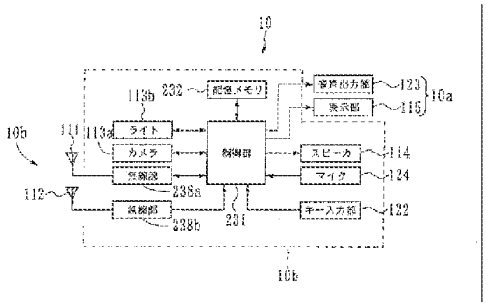
。

【符号の説明】
【0037】
１０…携帯電話機（無線通信機）、１１，３１，４１…第１の放射導体、１２，３２，４２…第２のアンテナ放射導体、１３，３３，４３…第１の給電部、１４，３４，４４…短絡部、１５，３５，４５…第２の給電部、１６，３６，４６…地導体（接地導体板）、２２…整合回路部、５１…第１のアンテナ、５２…第２のアンテナ、５３…筐体
５４…液晶ディスプレイ、５５…操作キー、１１１、１３１、１４１…第１のアンテナ、１１２、１３２、１４２…第２のアンテナ。

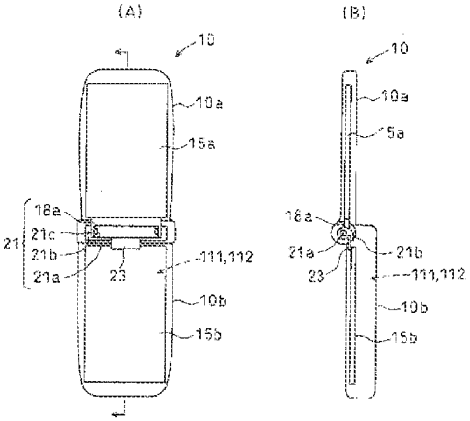
【図1】



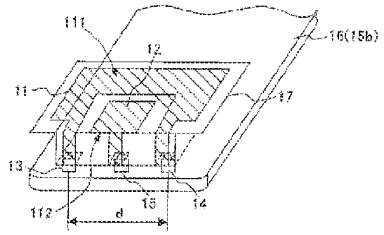
【図2】



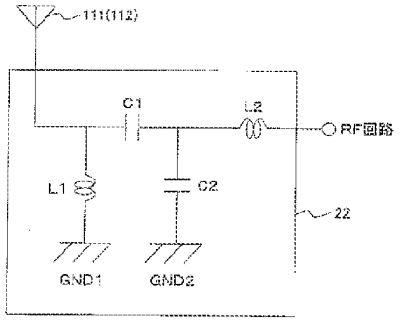
【図3】



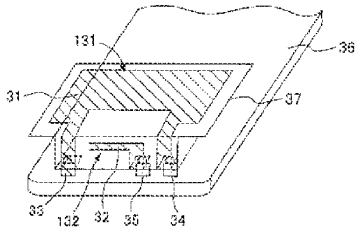
【図4】



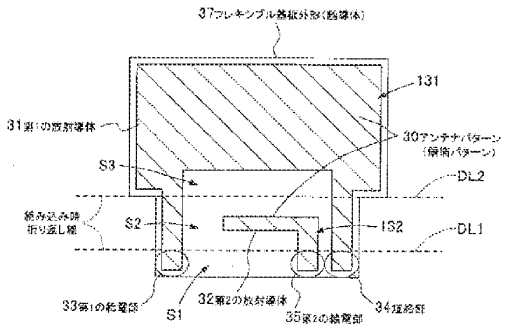
【図5】



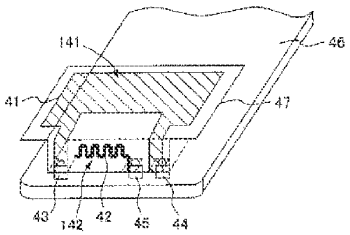
【図6】



【図7】



【図8】



【図9】

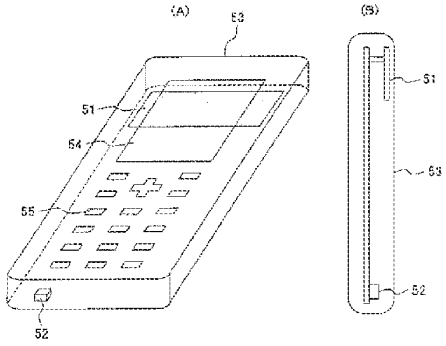


Fig. 10A

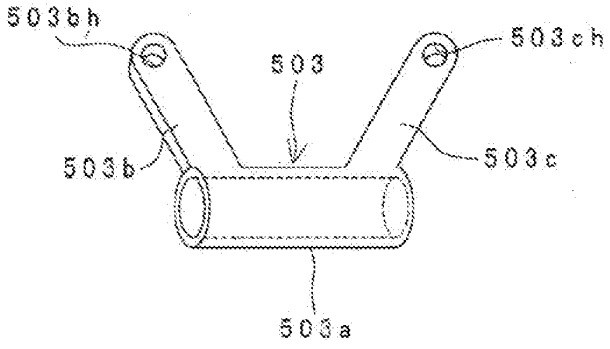
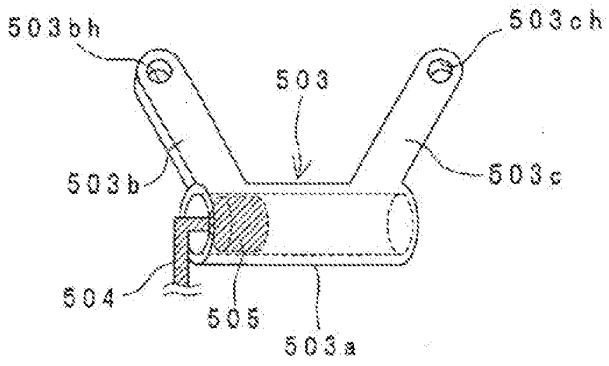


Fig. 10B



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Fig. 11A

FOURTH PREFERRED EMBODIMENT

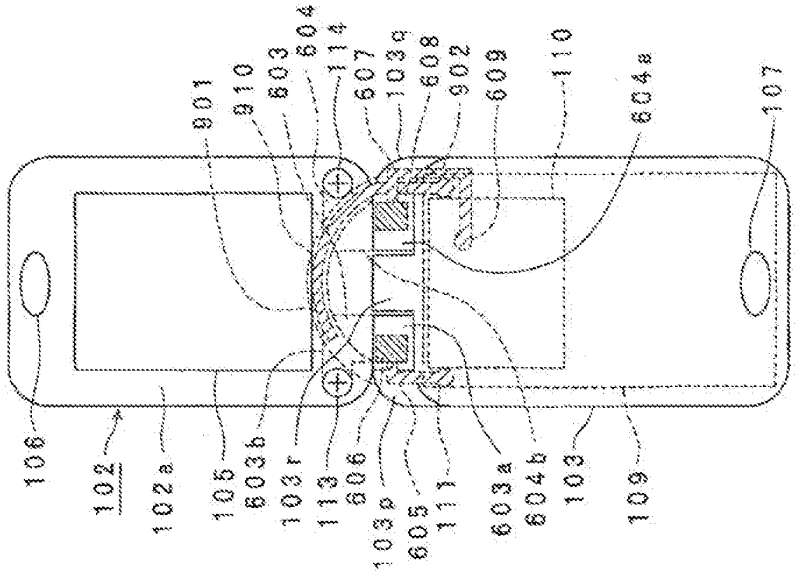
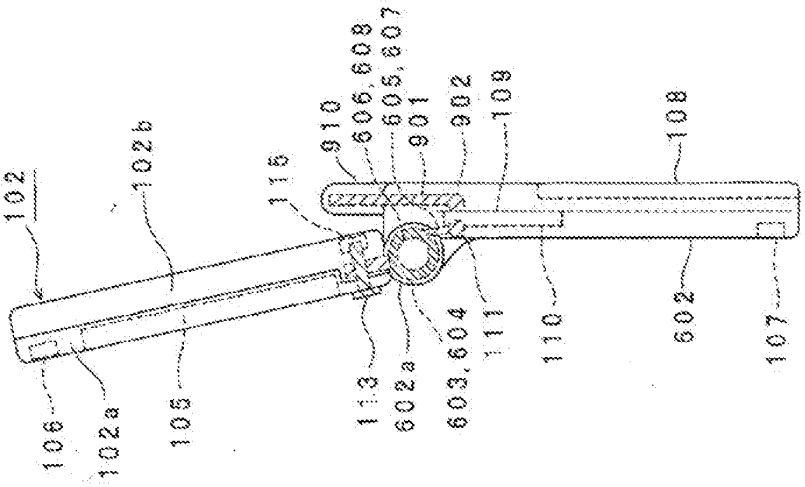


Fig. 11B



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Fig. 12A

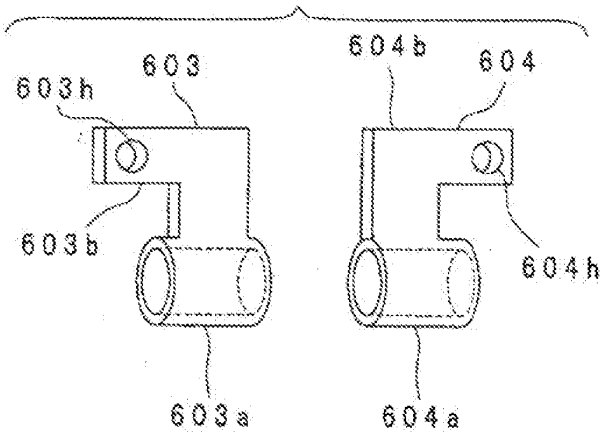
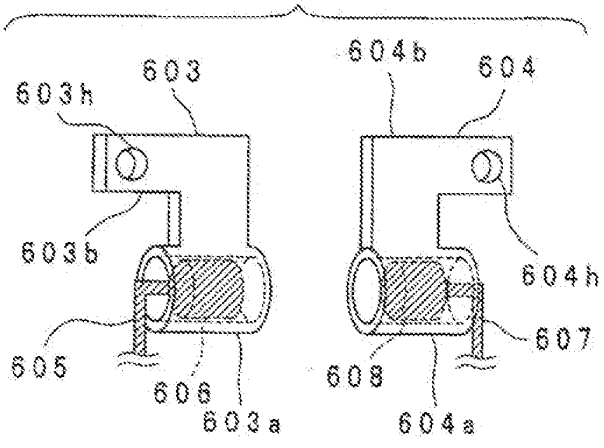
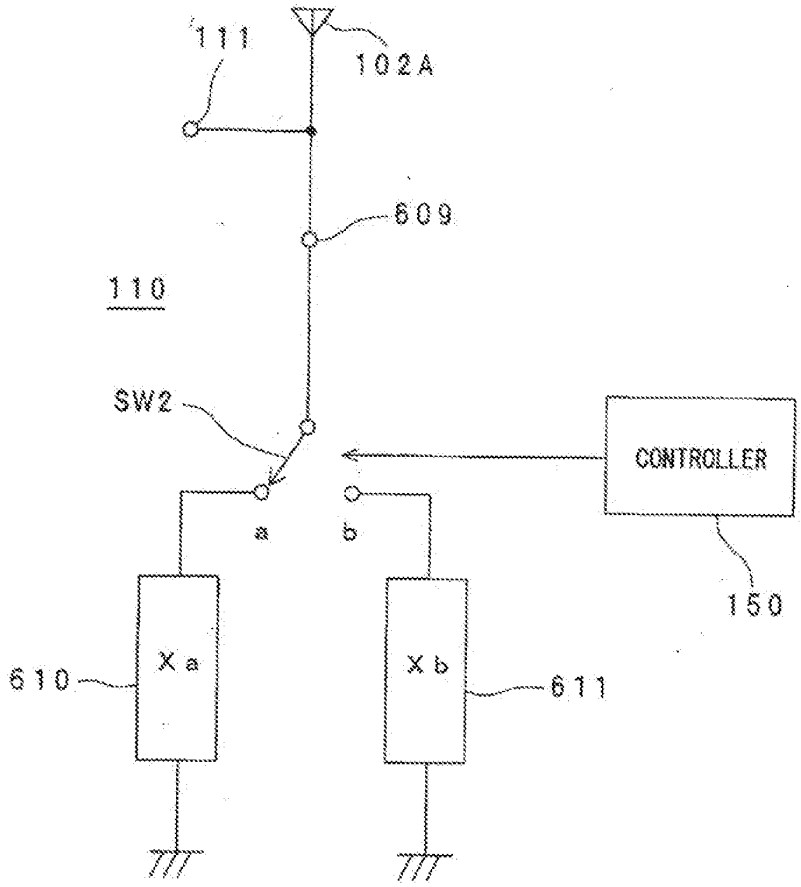


Fig. 12B



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Fig. 13



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Fig. 14B

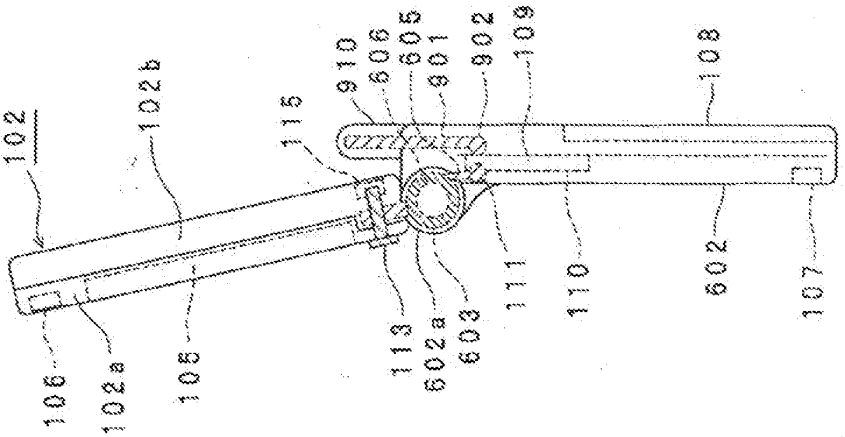


Fig. 14A

MODIFIED PREFERRED EMBODIMENT OF FOURTH PREFERRED EMBODIMENT

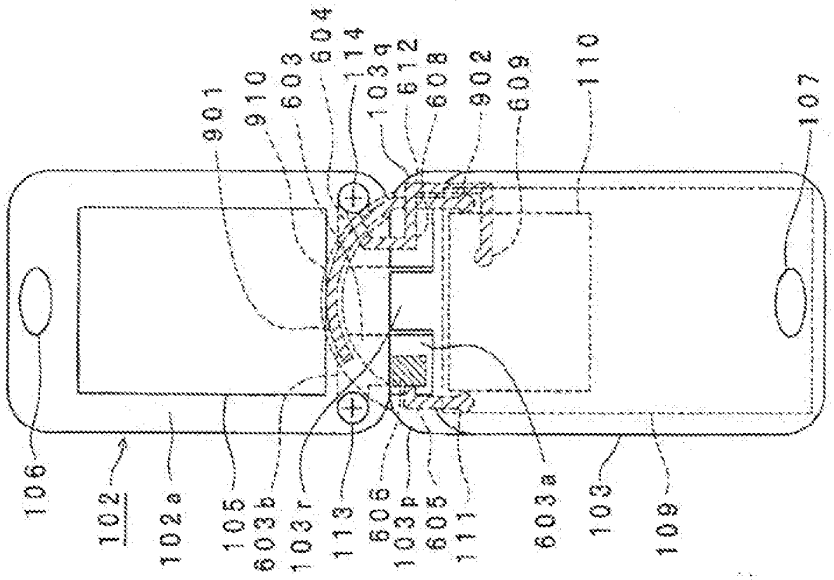


Fig. 15B

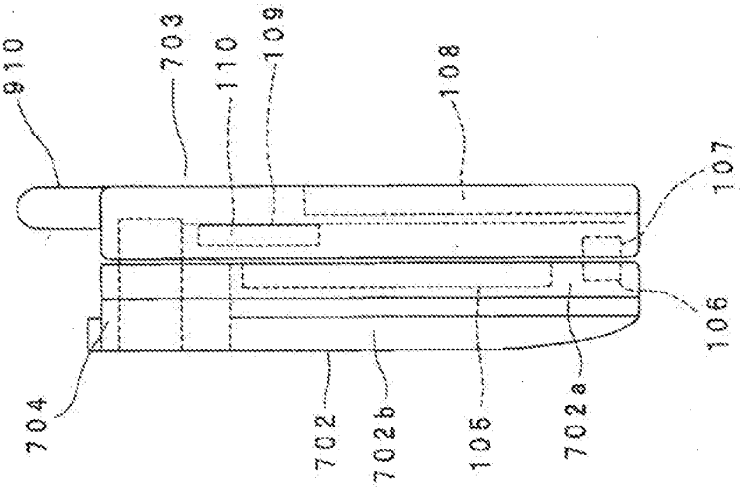
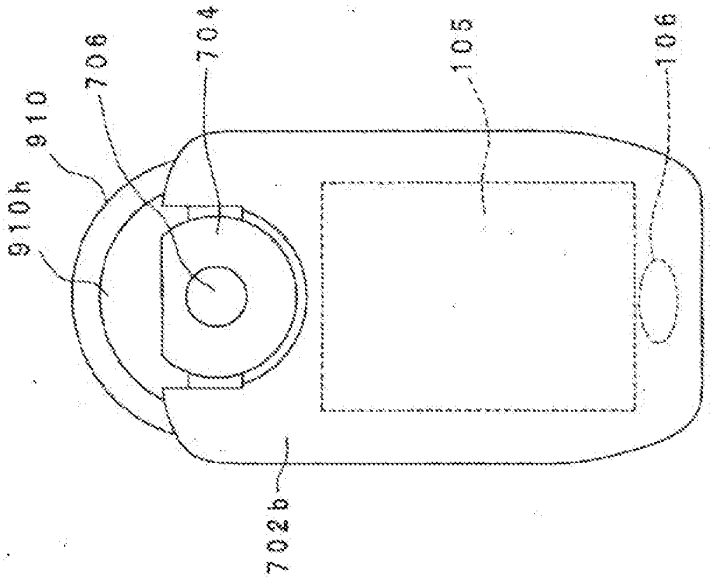


Fig. 15A

FIFTH PREFERRED EMBODIMENT



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Fig. 16

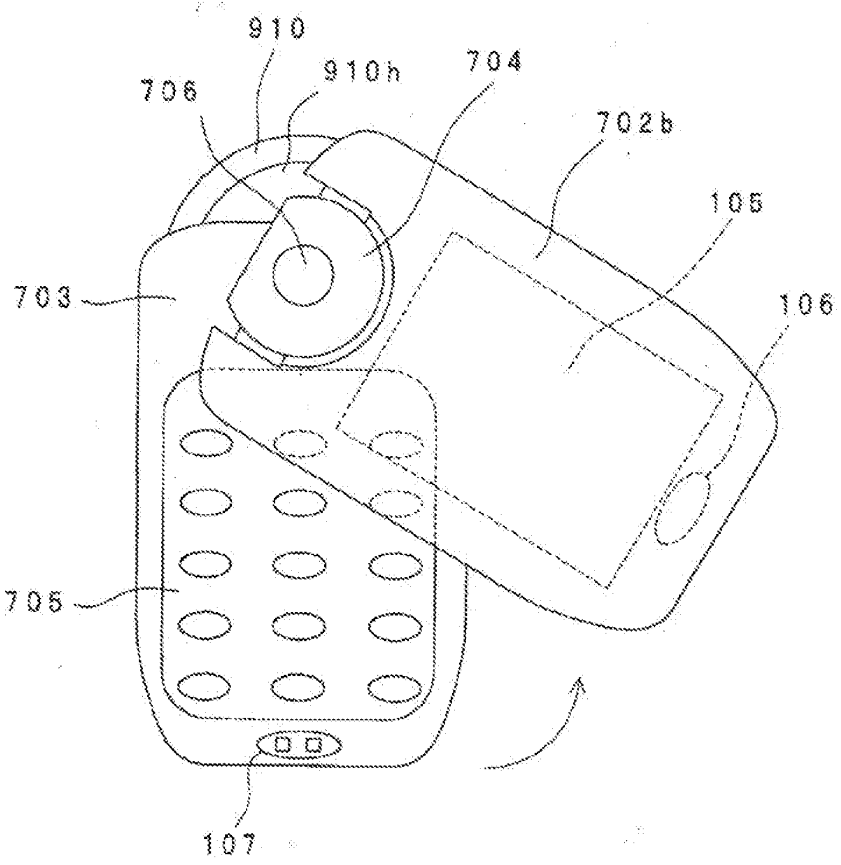


Fig. 17B

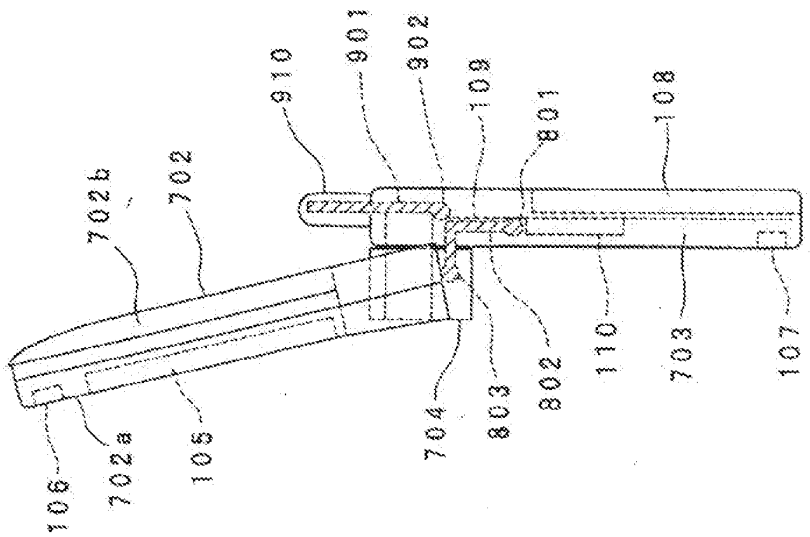
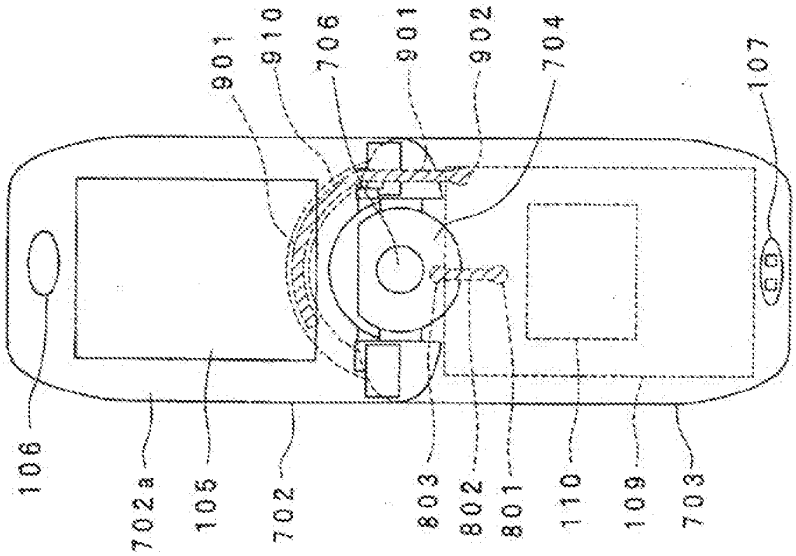


Fig. 17A



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Fig. 18

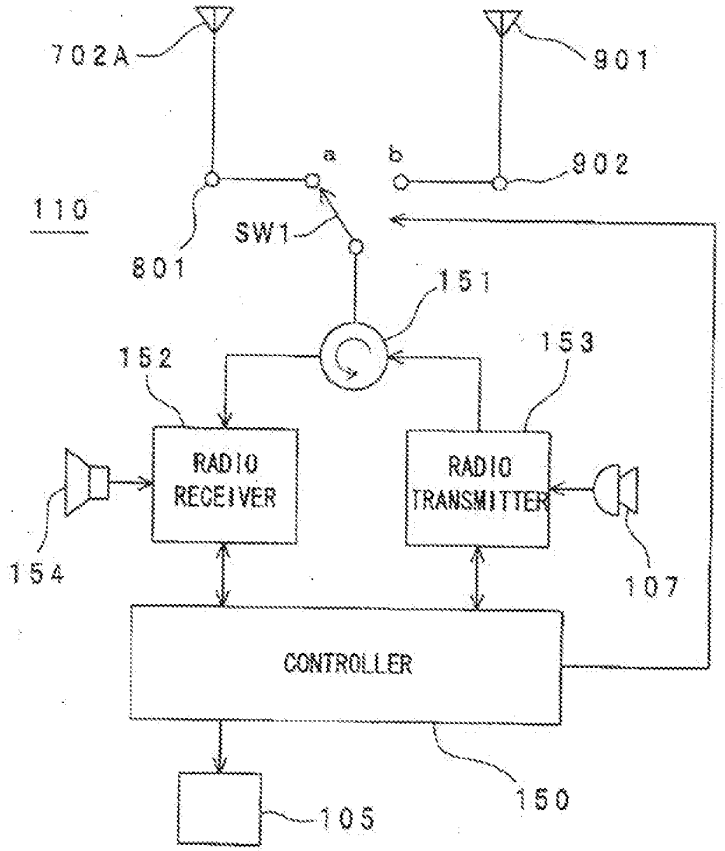

702A
901
a
b
902
110
801
SW1
151
152
153
RADIO RECEIVER
RADIO TRANSMITTER
154
107
CONTROLLER
105
150

Fig. 19A

MODIFIED PREFERRED EMBODIMENT OF FIFTH PREFERRED EMBODIMENT

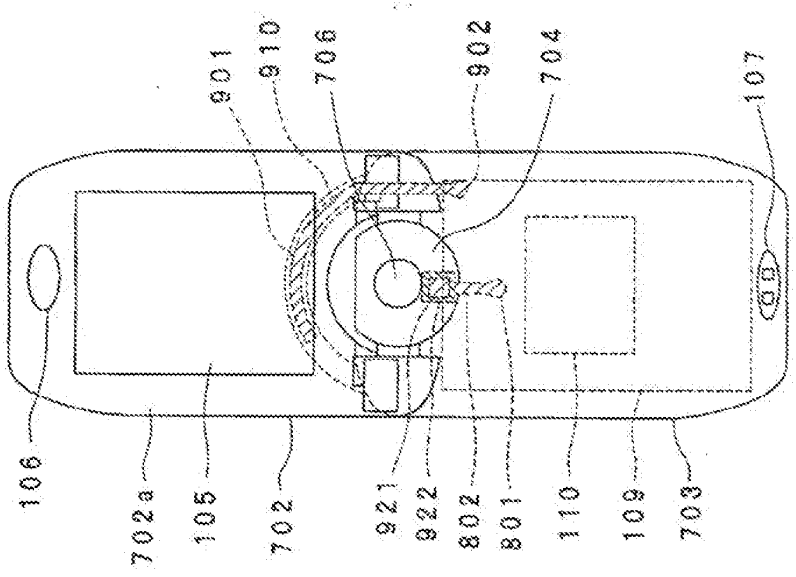
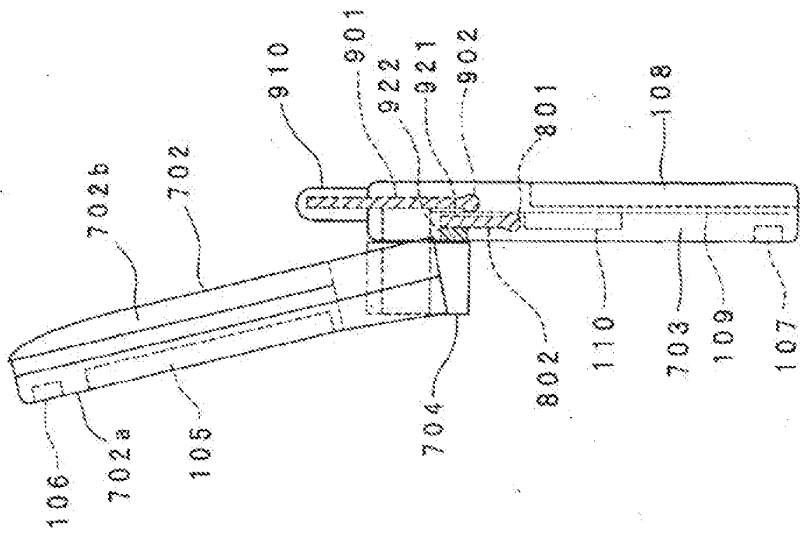


Fig. 19B



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Fig. 20

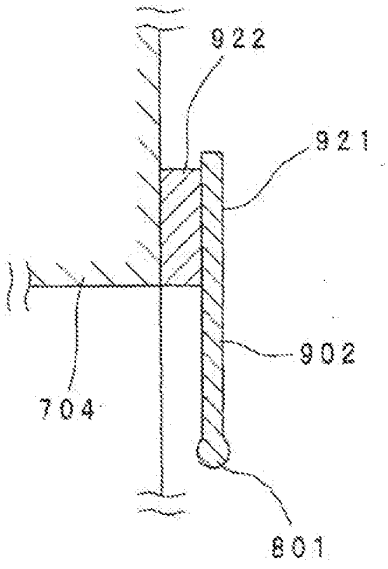
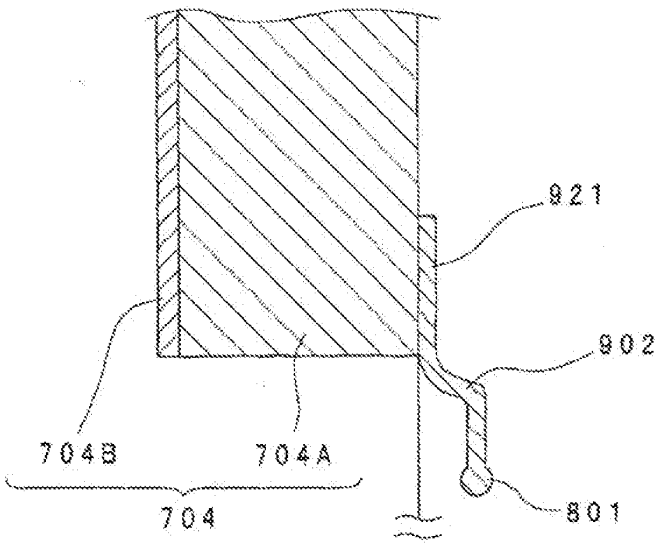


Fig. 21



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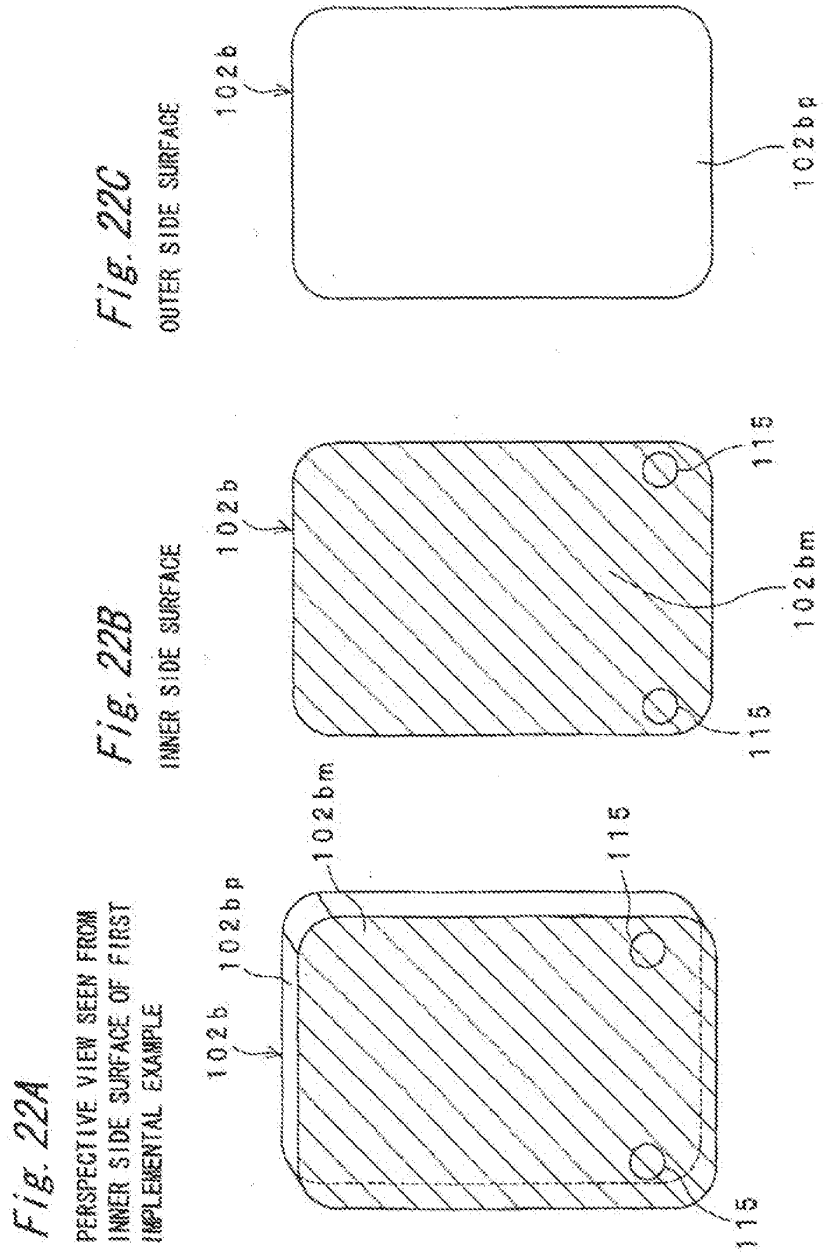


Fig. 22A
PERSPECTIVE VIEW SEEN FROM INNER SIDE SURFACE OF FIRST IMPLEMENTAL EXAMPLE

Fig. 22B
INNER SIDE SURFACE

Fig. 22C
OUTER SIDE SURFACE

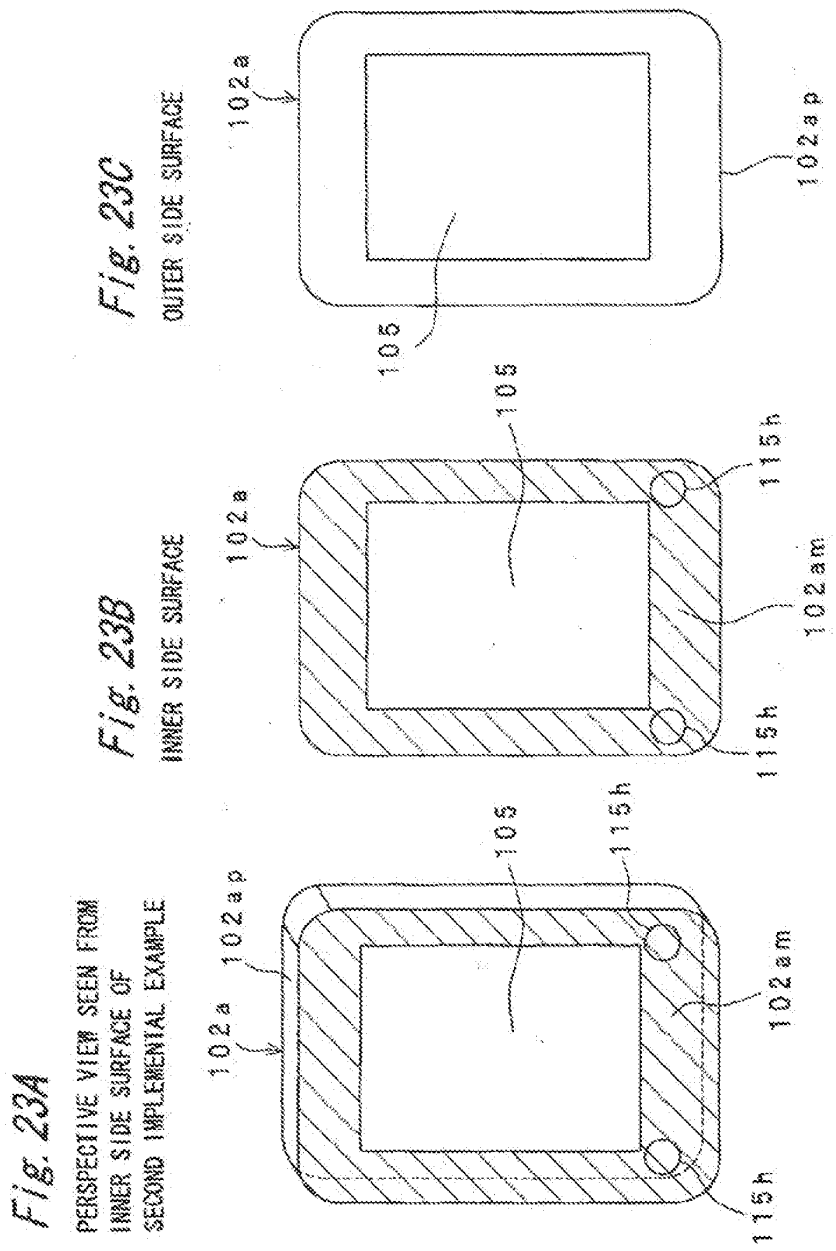


Fig. 23A
PERSPECTIVE VIEW SEEN FROM INNER SIDE SURFACE OF SECOND IMPLEMENTIAL EXAMPLE

Fig. 23B
INNER SIDE SURFACE

Fig. 23C
OUTER SIDE SURFACE

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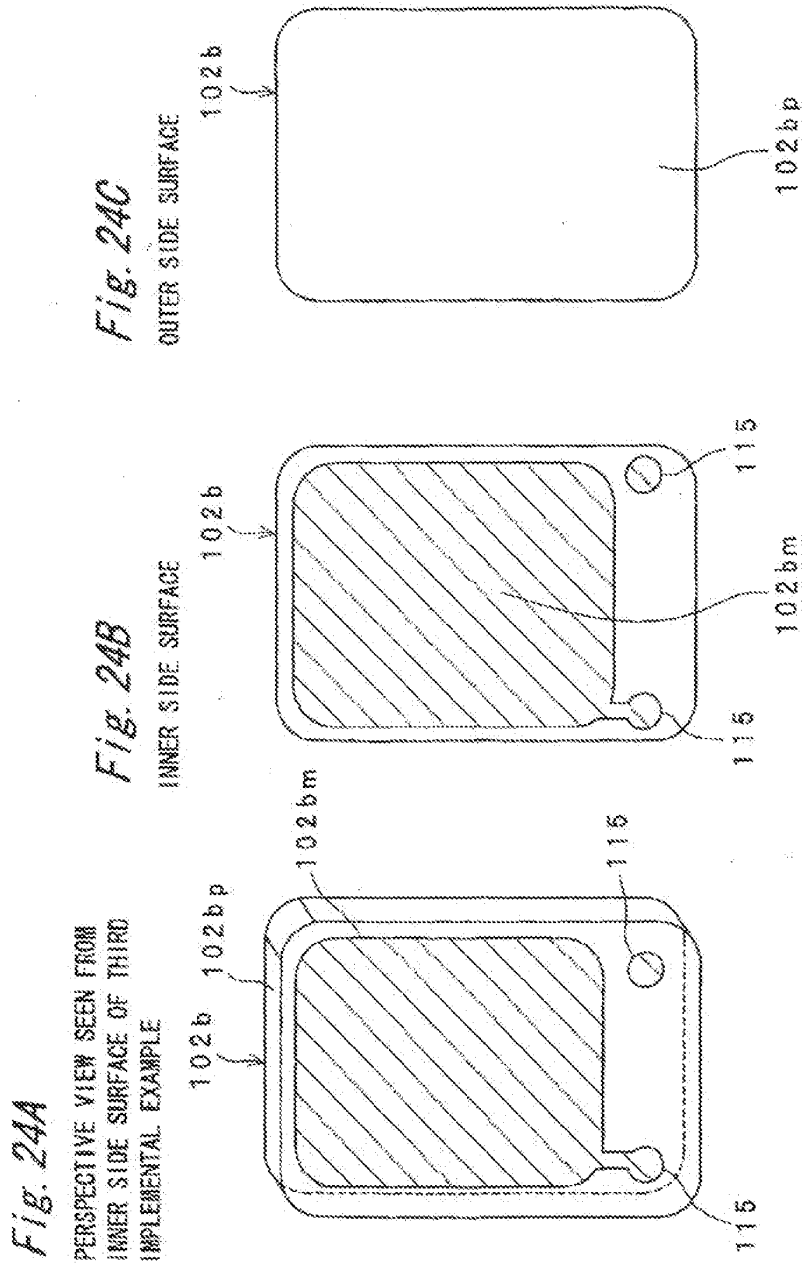


Fig. 24A
PERSPECTIVE VIEW SEEN FROM INNER SIDE SURFACE OF THIRD IMPLEMENTAL EXAMPLE

Fig. 24B
INNER SIDE SURFACE

Fig. 24C
OUTER SIDE SURFACE

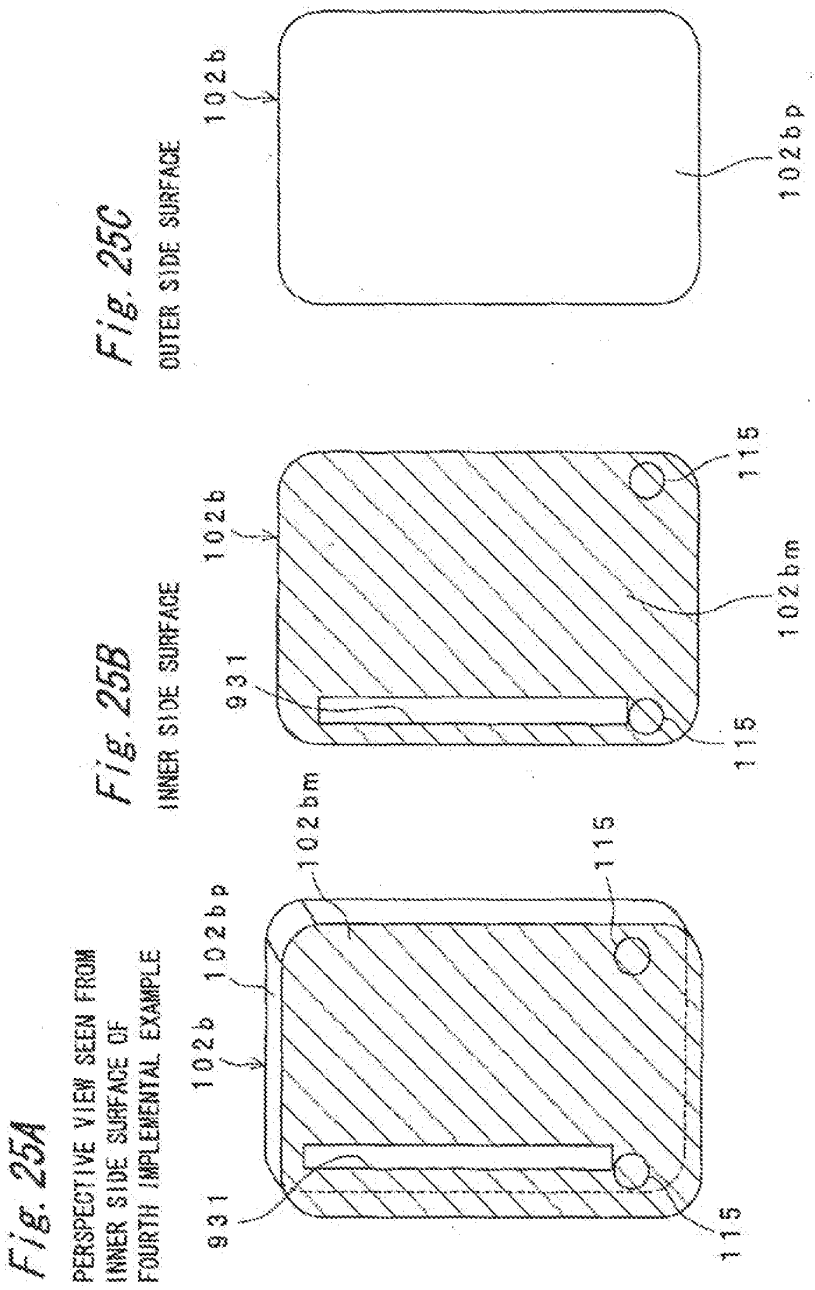


Fig. 25A
PERSPECTIVE VIEW SEEN FROM INNER SIDE SURFACE OF FOURTH IMPLEMENTAL EXAMPLE

Fig. 25B
INNER SIDE SURFACE

Fig. 25C
OUTER SIDE SURFACE

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Fig. 27C
OUTER SIDE SURFACE

Fig. 27B
INNER SIDE SURFACE

Fig. 27A
PERSPECTIVE VIEW SEEN FROM INNER SIDE SURFACE OF SIXTH IMPLEMENTAL EXAMPLE

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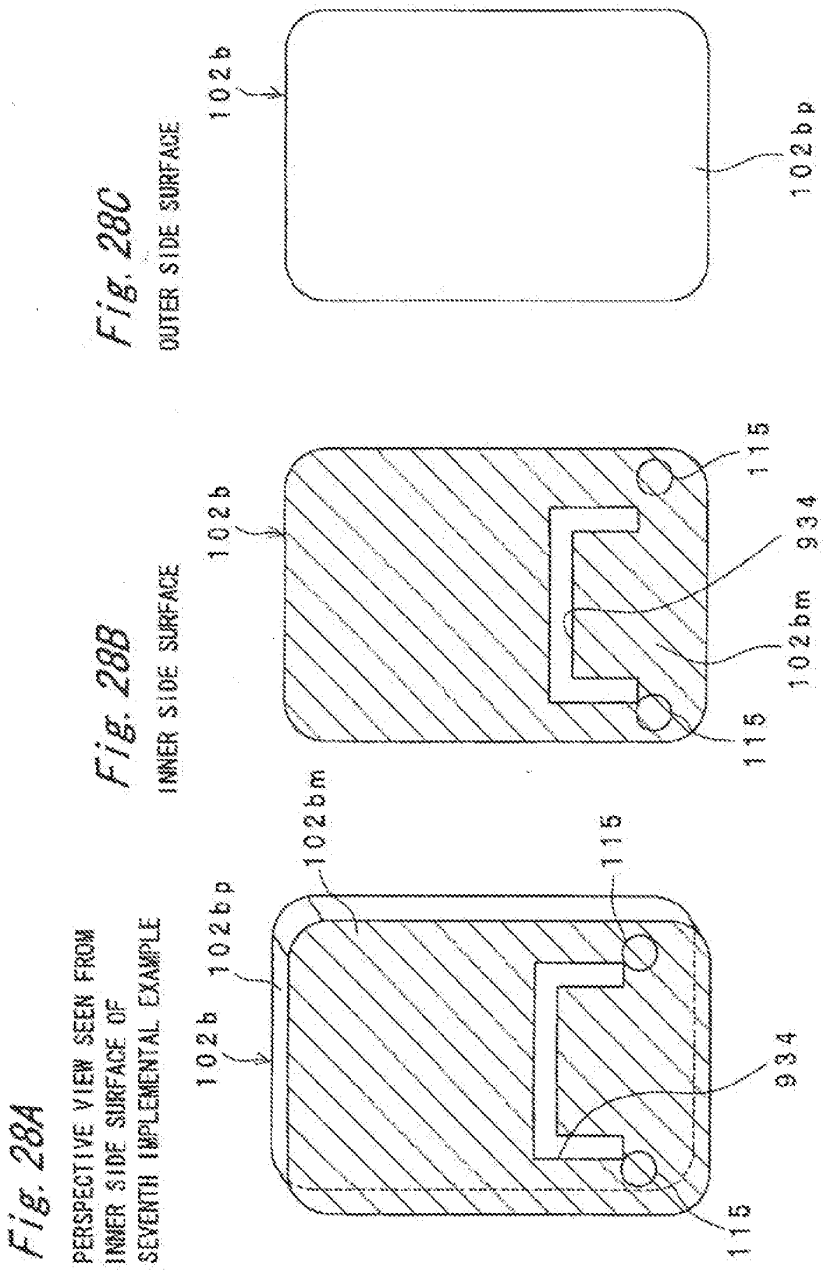


Fig. 28A
PERSPECTIVE VIEW SEEN FROM INNER SIDE SURFACE OF SEVENTH IMPLEMENTAL EXAMPLE

Fig. 28B
INNER SIDE SURFACE

Fig. 28C
OUTER SIDE SURFACE

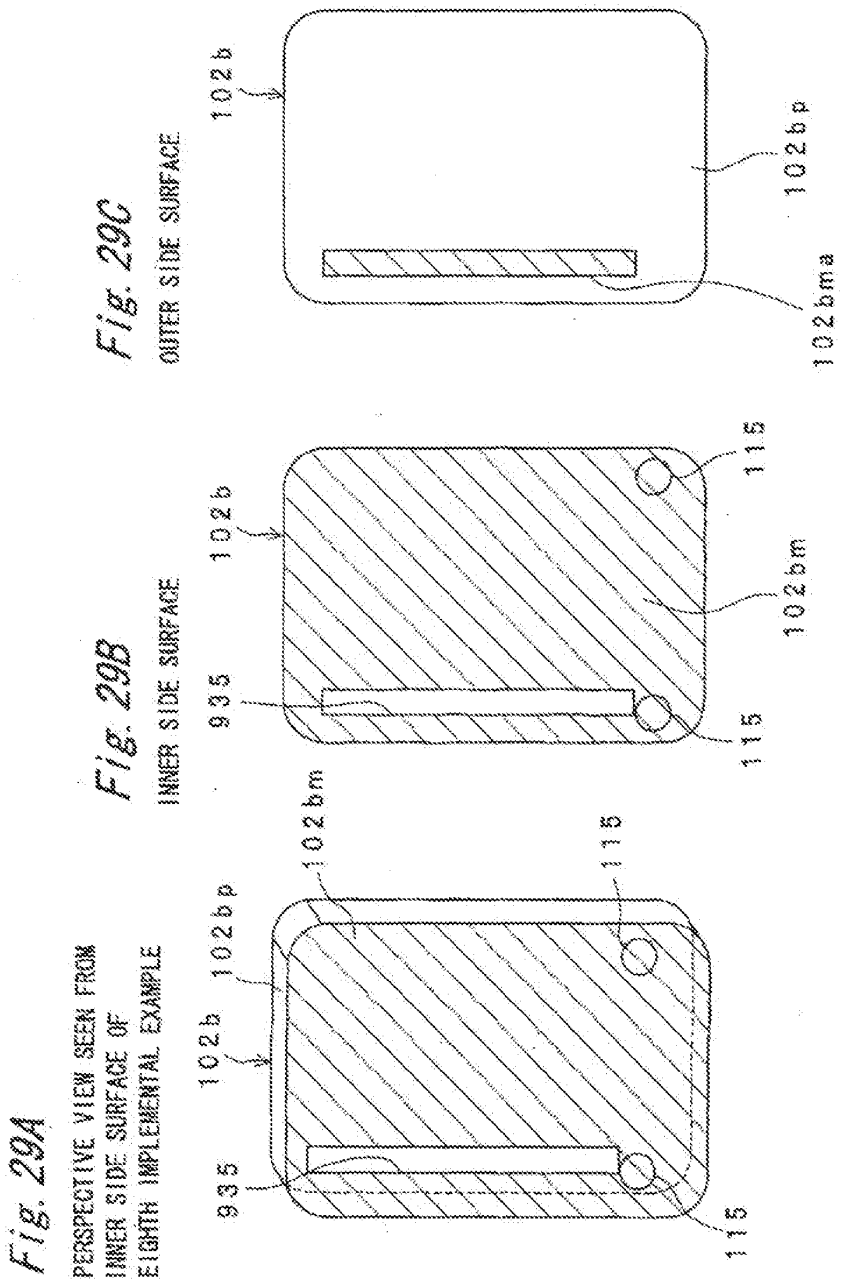


Fig. 29C
OUTER SIDE SURFACE

Fig. 29B
INNER SIDE SURFACE

Fig. 29A
PERSPECTIVE VIEW SEEN FROM INNER SIDE SURFACE OF EIGHTH IMPLEMENTAL EXAMPLE

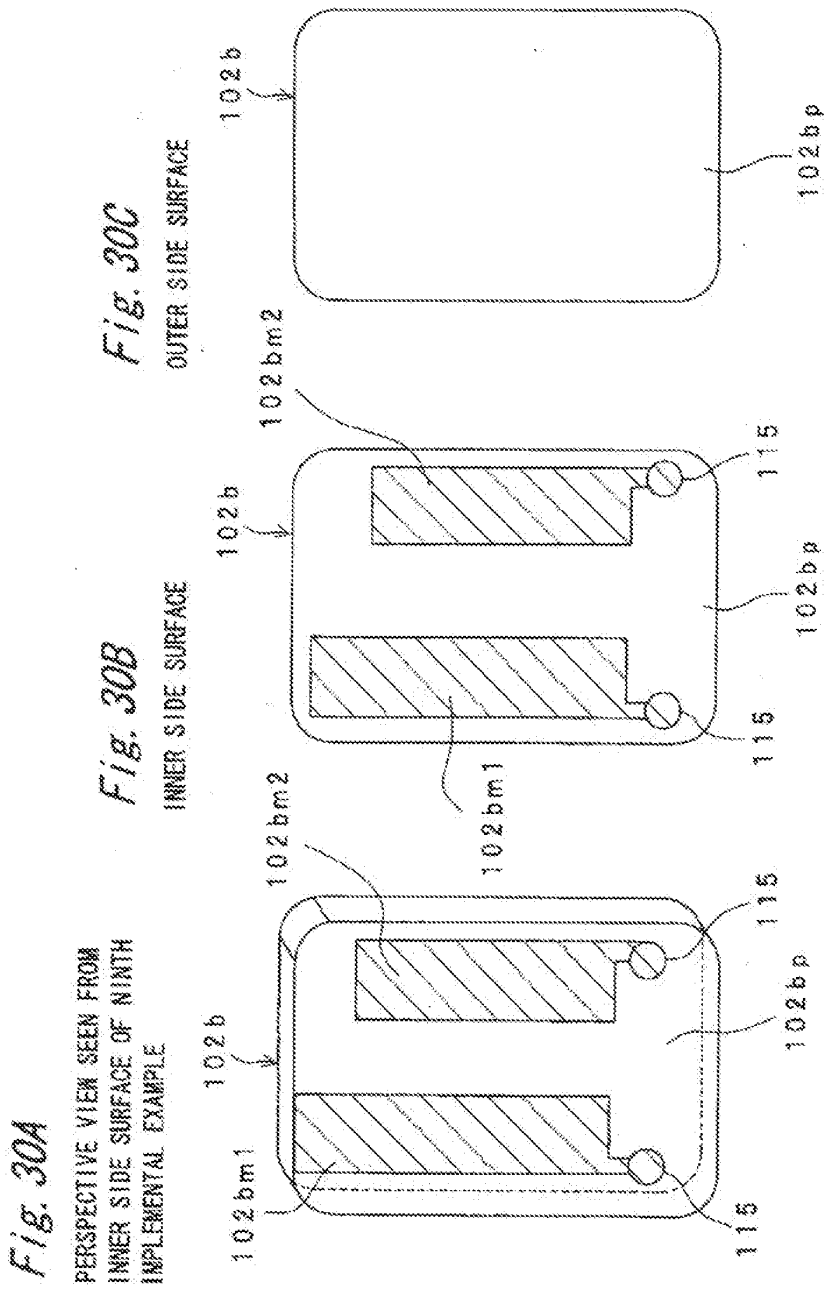


Fig. 30A
PERSPECTIVE VIEW SEEN FROM INNER SIDE SURFACE OF NINTH IMPLEMENTAL EXAMPLE

Fig. 30B
INNER SIDE SURFACE

Fig. 30C
OUTER SIDE SURFACE

Fig. 31B

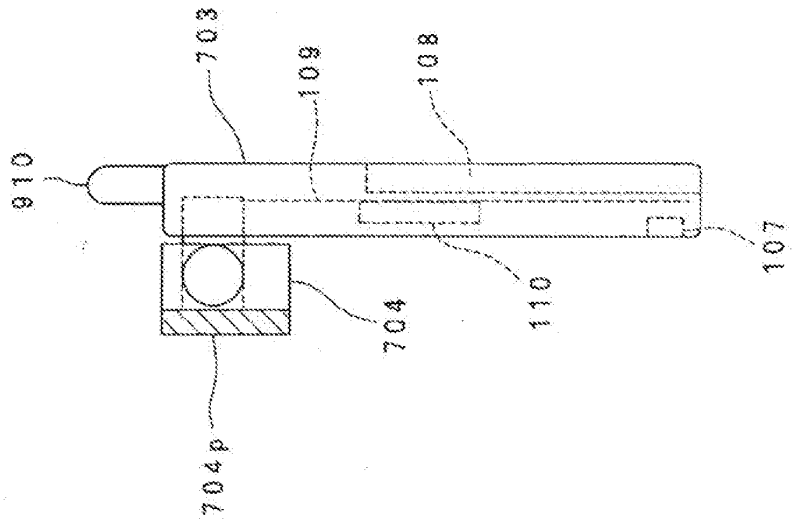


Fig. 31A

TENTH IMPLEMENTAL EXAMPLE

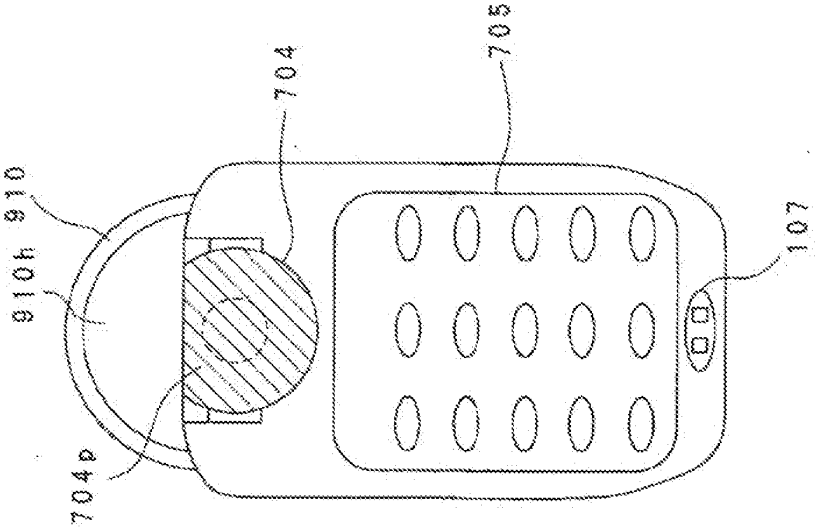


Fig. 32B

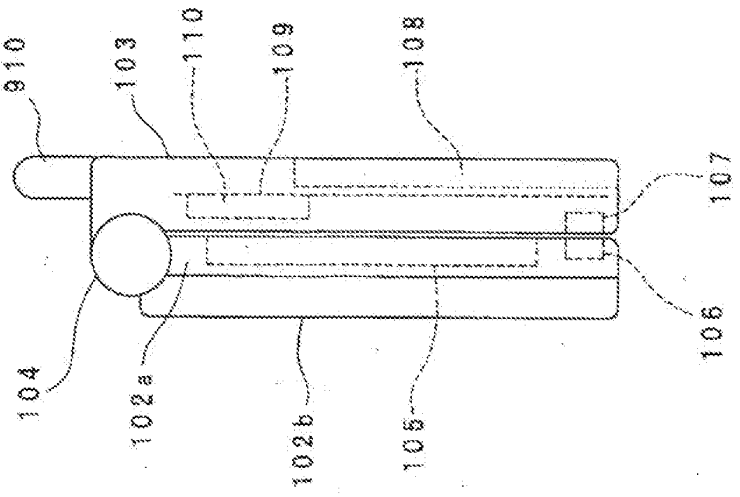
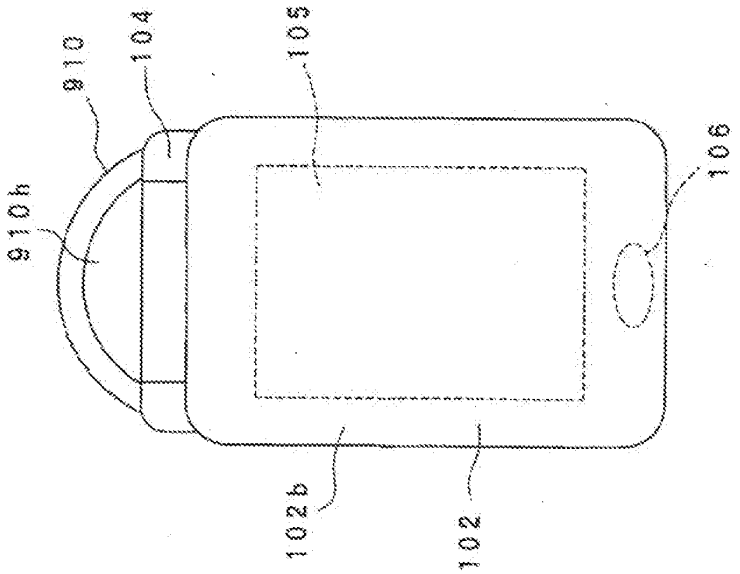


Fig. 32A

SIXTH PREFERRED EMBODIMENT



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Fig. 33B

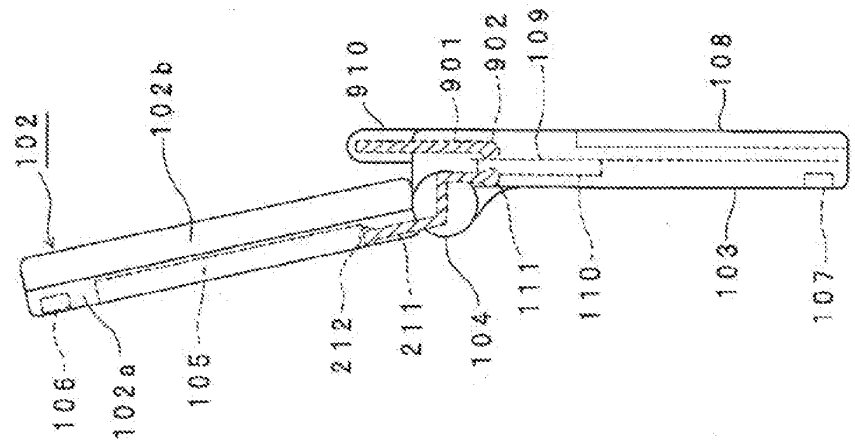
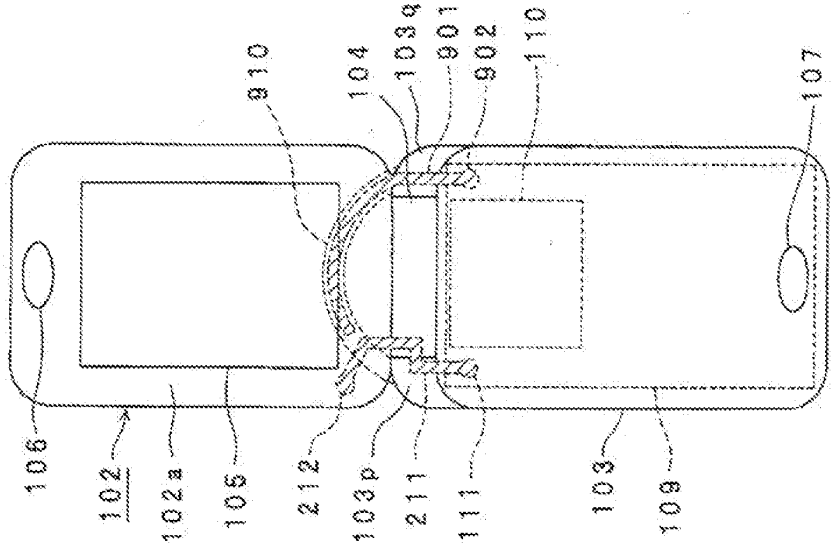


Fig. 33A



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Fig. 34

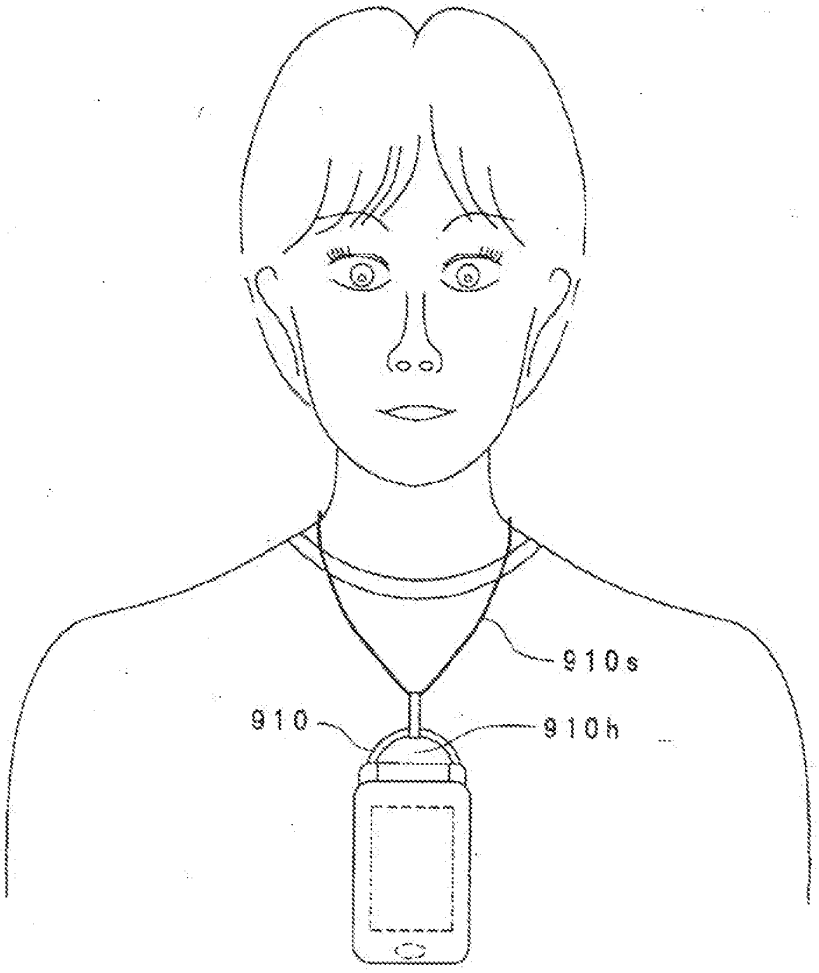


Fig. 35A

MODIFIED PREFERRED EMBODIMENT OF SIXTH PREFERRED EMBODIMENT

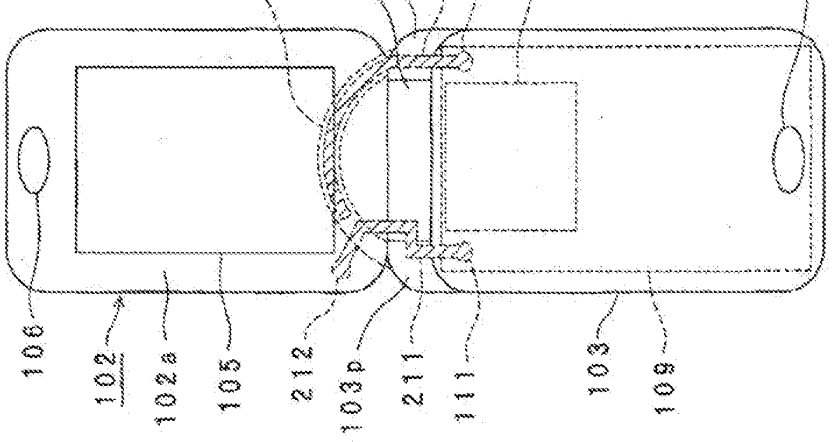
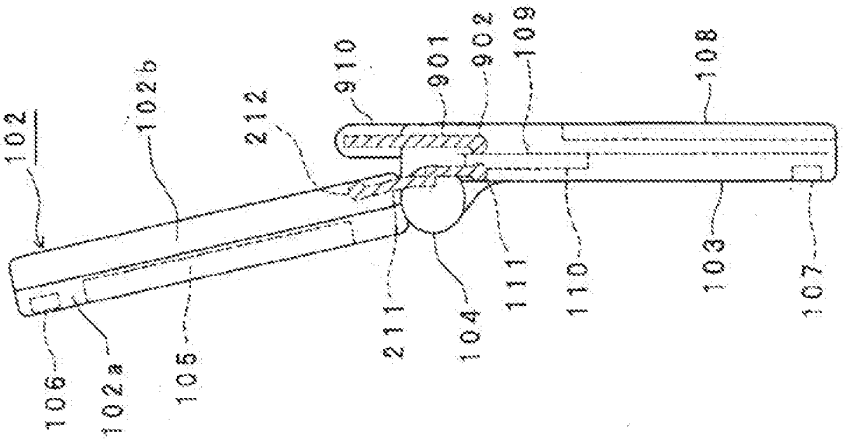


Fig. 35B



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Fig. 36A

SEVENTH PREFERRED EMBODIMENT

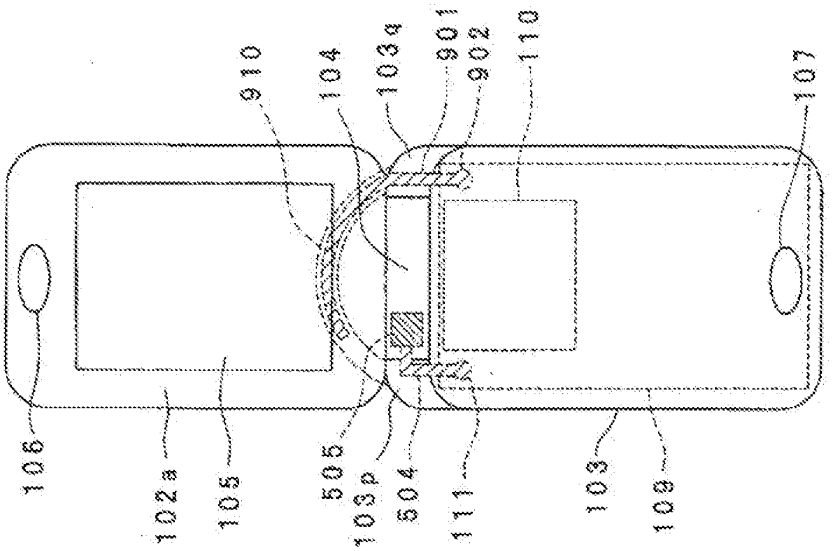
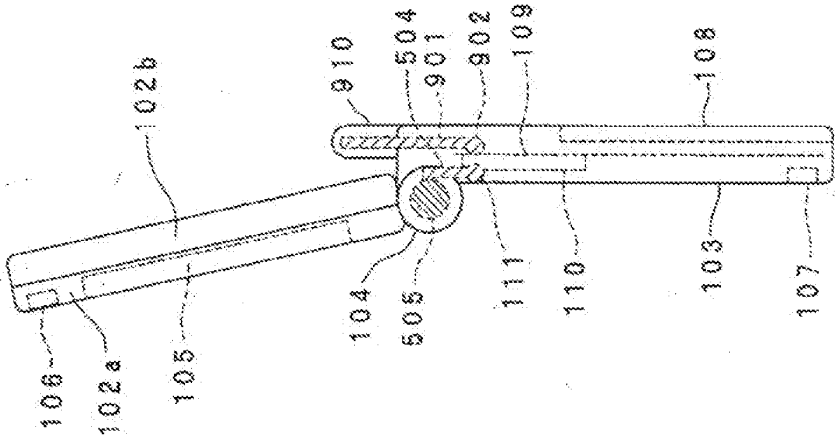


Fig. 36B



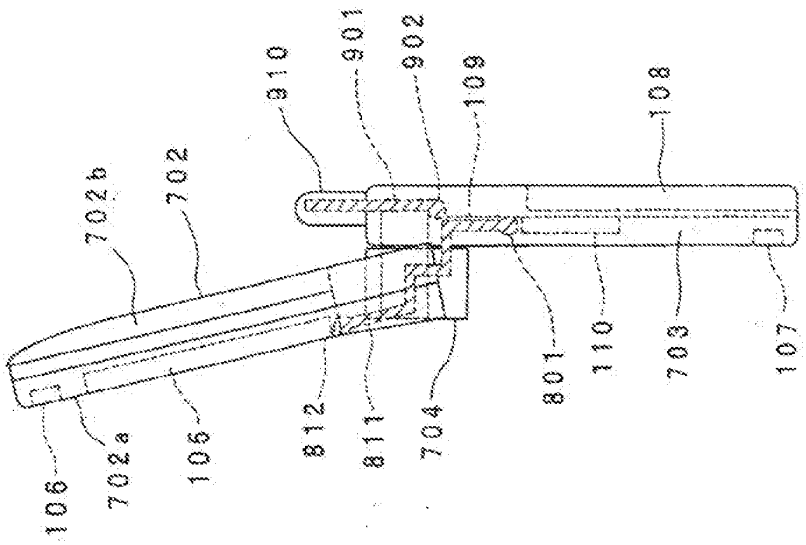


Fig. 37B

Fig. 37A

EIGHTH PREFERRED EMBODIMENT

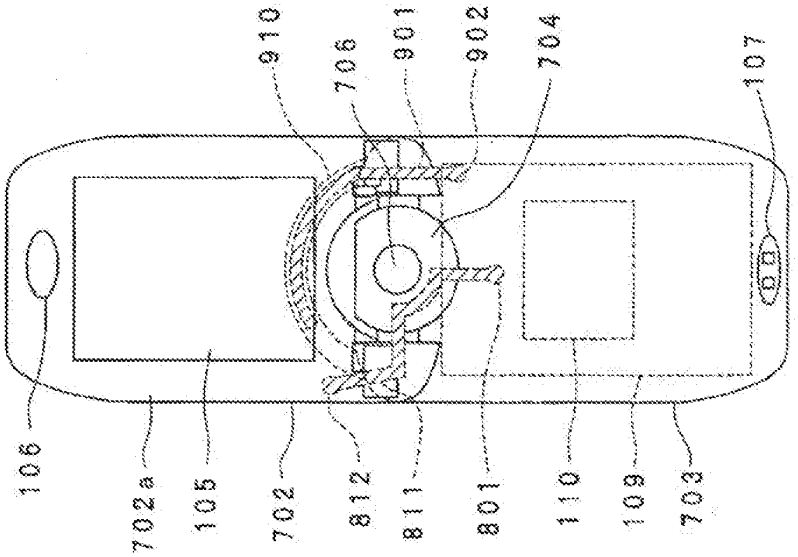


Fig. 38B

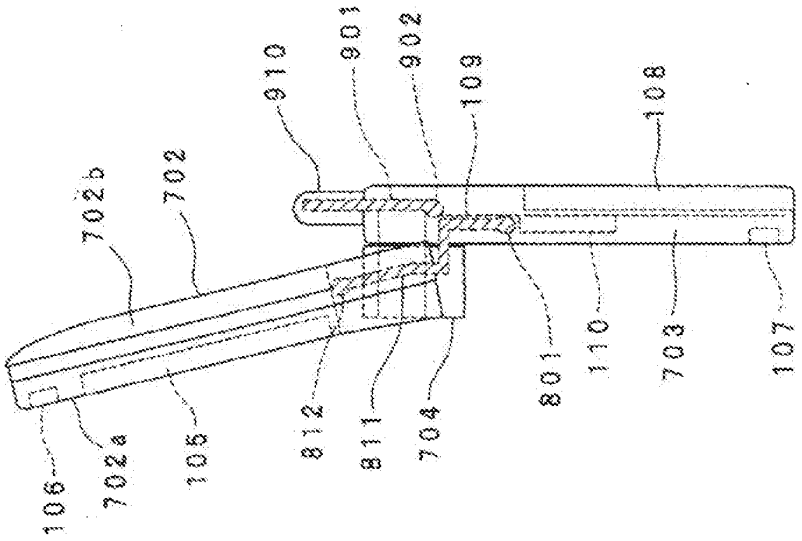
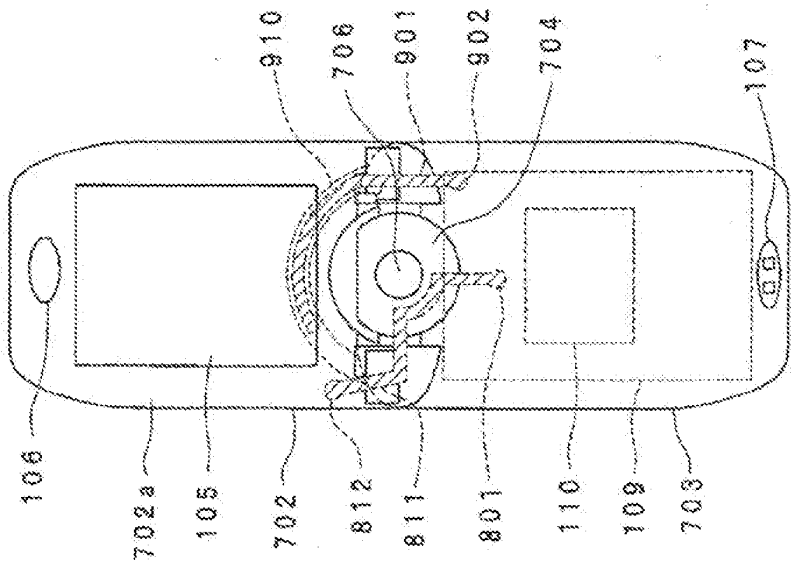


Fig. 38A

MODIFIED PREFERRED EMBODIMENT
OF EIGHTH PREFERRED EMBODIMENT



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Fig. 39B

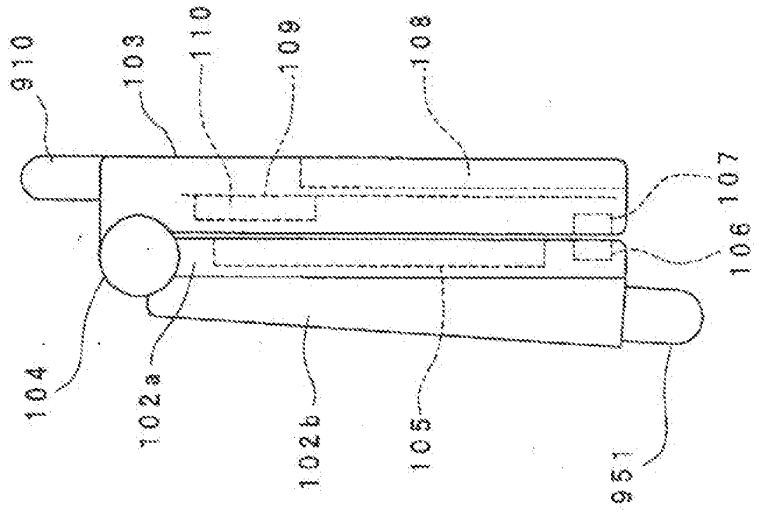


Fig. 39A

WITH PREFERRED EMBODIMENT

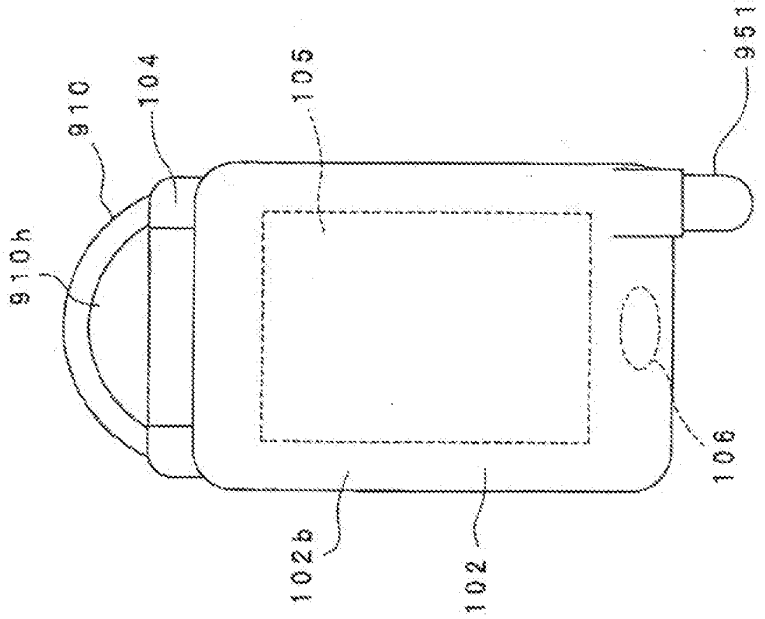


Fig. 40B

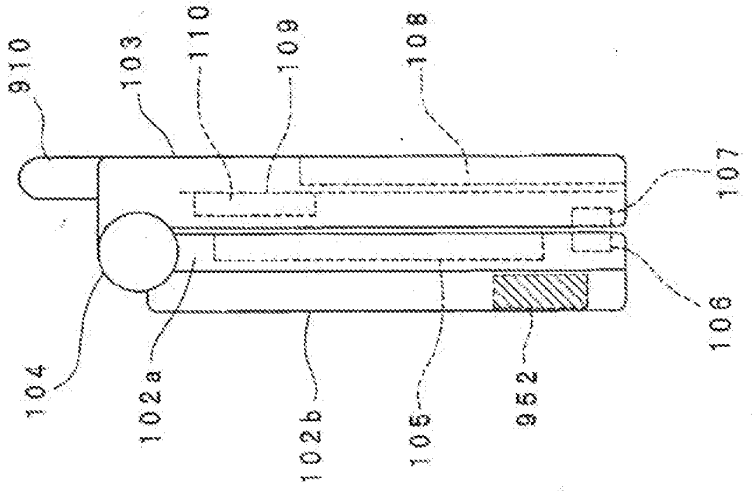


Fig. 40A

TENTH PREFERRED EMBODIMENT

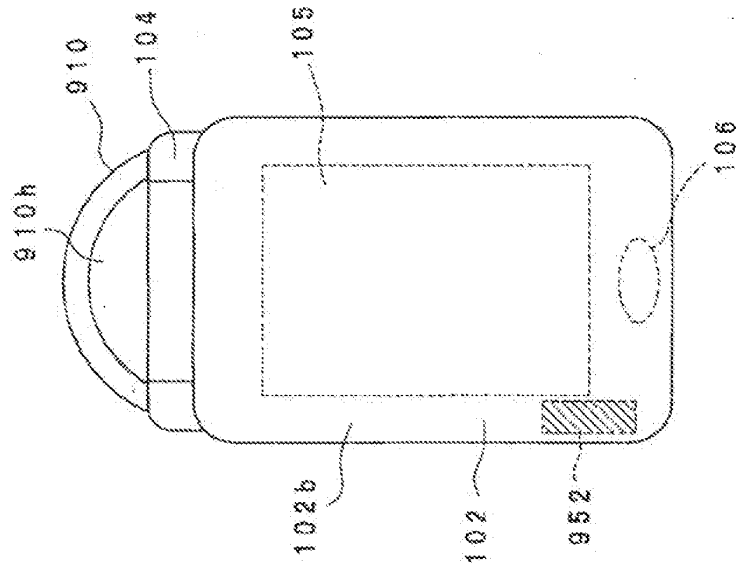


Fig. 41B

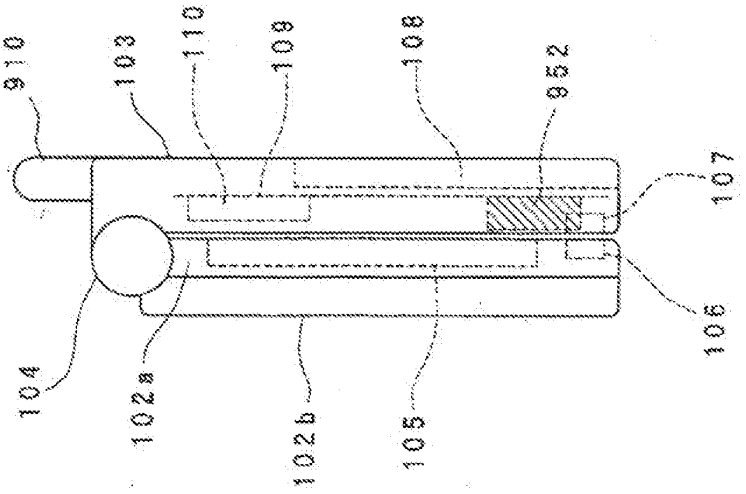


Fig. 41A

MODIFIED PREFERRED EMBODIMENT
OF TENTH PREFERRED EMBODIMENT

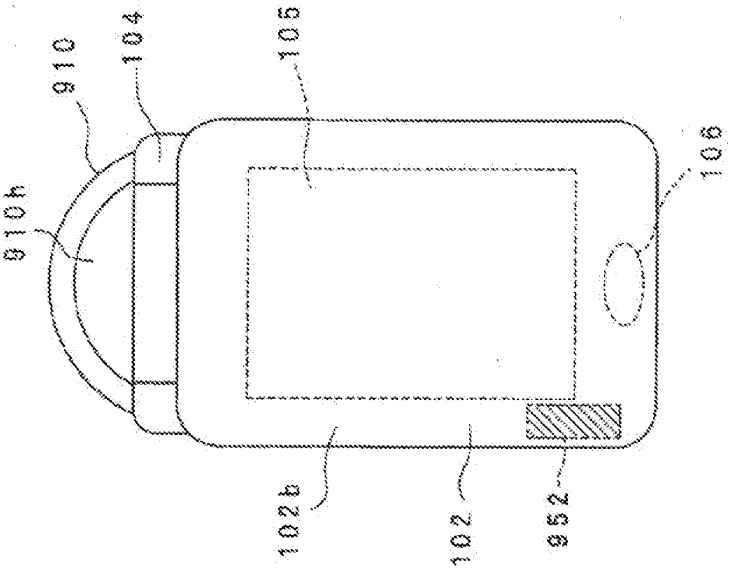


Fig. 42B

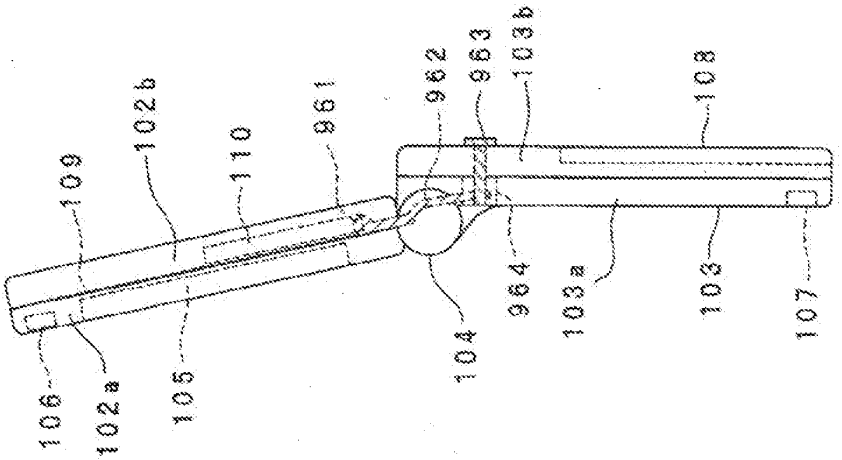


Fig. 42A

ELEVENTH PREFERRED EMBODIMENT

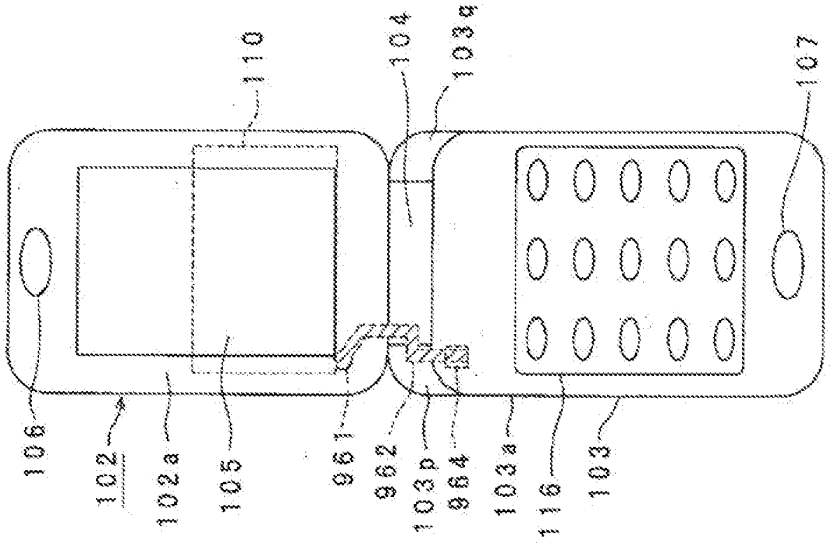


Fig. 43

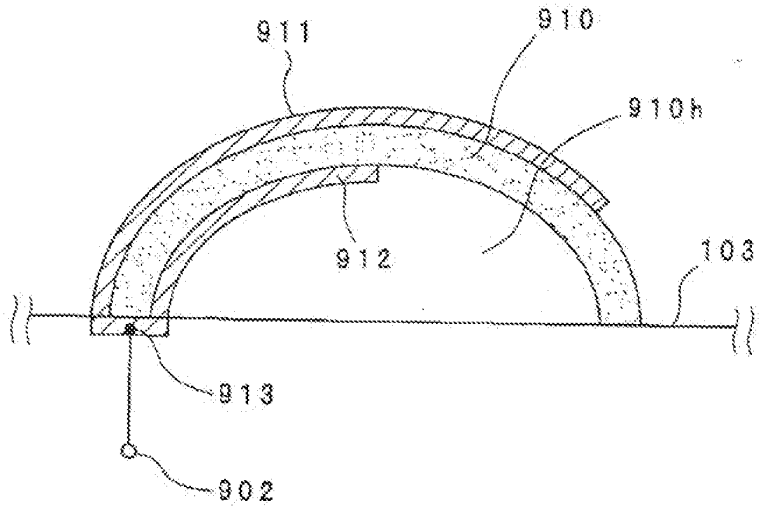


Fig. 44B

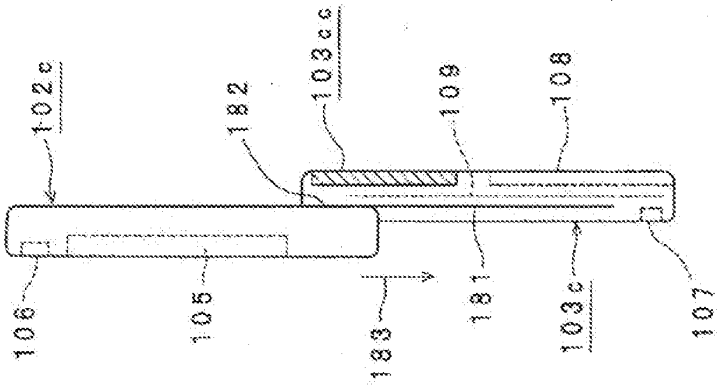
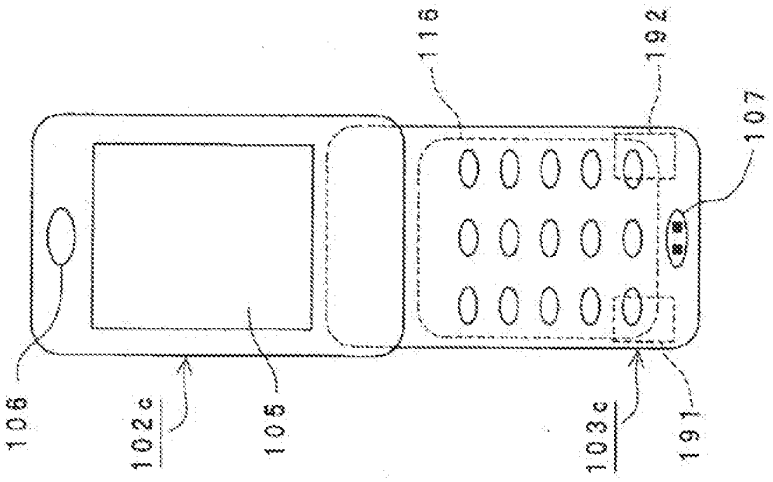


Fig. 44A

TWELFTH PREFERRED EMBODIMENT



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Fig. 45B

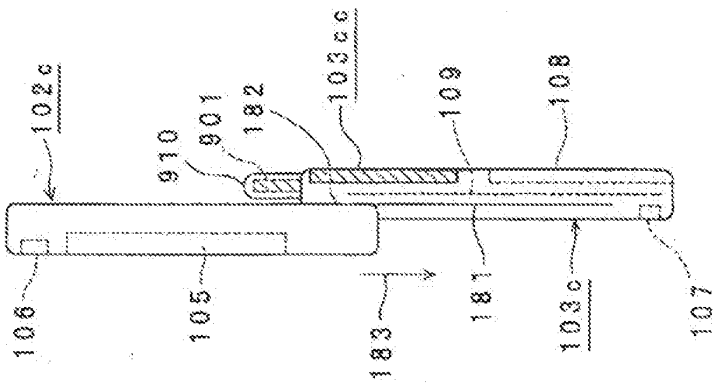


Fig. 45A

MODIFIED PREFERRED EMBODIMENT OF TWELFTH PREFERRED EMBODIMENT

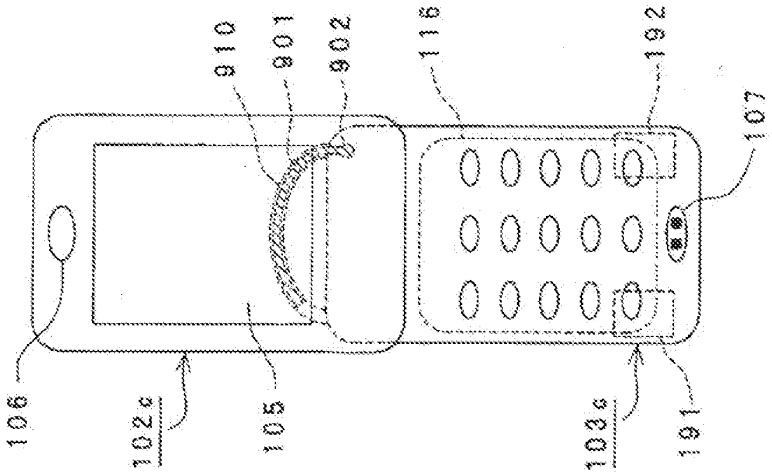


Fig. 46C

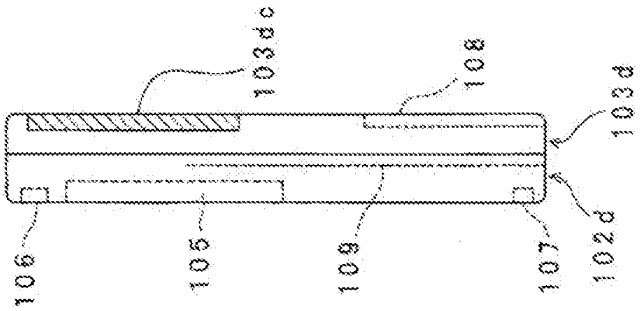


Fig. 46B

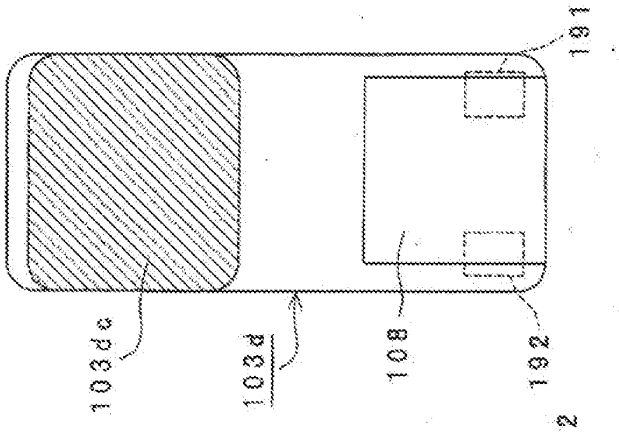
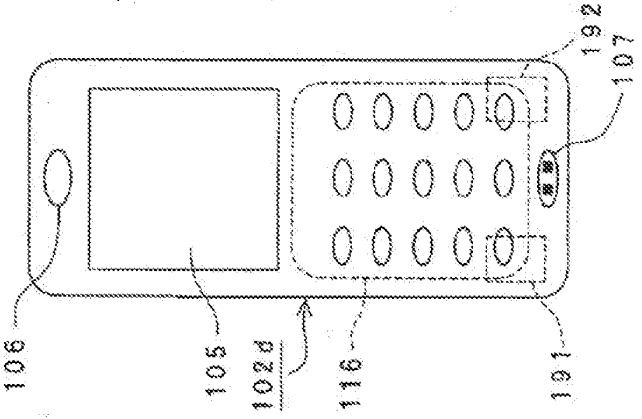


Fig. 46A

THIRTEENTH PREFERRED EMBODIMENT



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Fig. 47C

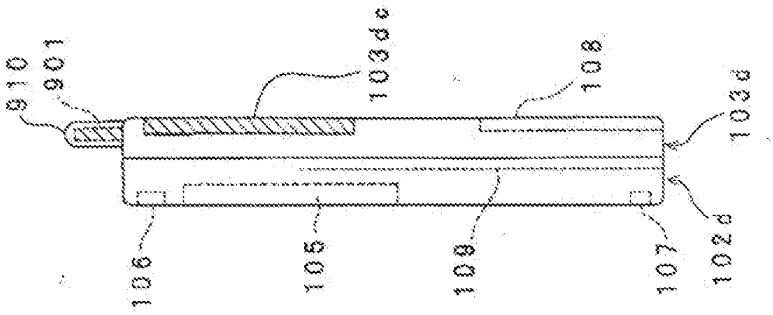


Fig. 47B

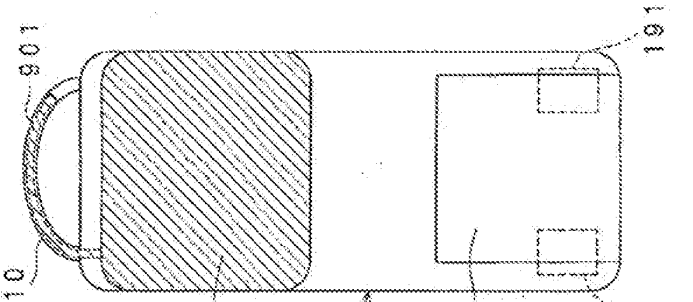
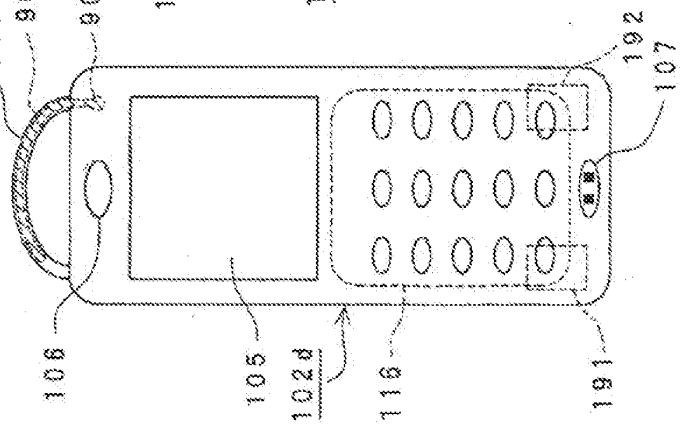


Fig. 47A

MODIFIED PREFERRED EMBODIMENT OF THIRTEENTH PREFERRED EMBODIMENT



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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 00 2024

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	10 May 2004	Wattiaux, V

CATEGORY OF CITED DOCUMENTS

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

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 04 00 2024

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

(11) EP 1 445 821 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
11.08.2004 Bulletin 2004/33

(21) Application number: **04002024.0**

(22) Date of filing: **30.01.2004**

(51) Int Cl.7: **H01Q 1/22**, H01Q 1/24, H01Q 1/27, H01Q 1/38, H01Q 5/00

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR
Designated Extension States:
AL LT LV MK

(30) Priority: **06.02.2003 JP 2003029217**
20.02.2003 JP 2003042822

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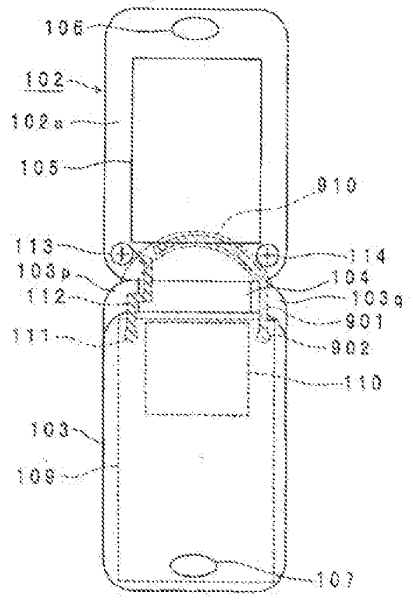
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Patentanwälte Rechtsanwälte
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(54) Portable radio communication apparatus provided with a boom portion

(57) In a portable radio communication apparatus including a housing, at least one part of at least one of the housing is formed as a housing electrical conductor portion by an electrically conductive material. The housing electrical conductor portion is connected with a radio communication circuit of the portable radio communication apparatus so as to operate as at least one part of an unbalanced type antenna of the radio communication circuit. Further, the portable radio communication apparatus further includes a boom portion coupled with the housing at least at two positions so as to provide at least one penetrating hole between the housing and the boom portion.

Fig. 1A

FIRST PREFERRED EMBODIMENT



EP 1 445 821 A1

Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

[0001] The present invention relates to a portable radio communication apparatus including a housing, and in particular, relates to a potable radio communication apparatus provided with a boom portion and a part of housing operating as an antenna.

2. DESCRIPTION OF THE RELATED ART

[0002] Recently, portable radio communication apparatuses such as cellular phones have been increasingly made smaller in size and thinner. In addition, the portable radio communication apparatuses have been not only used as conventional cellular phones but also transformed to data terminal apparatuses for transmitting and receiving E-mails and for viewing web pages through WWW (World Wide Web). Due to this, liquid crystal displays have been made larger in size. In these circumstances, folding cellular phone terminals, which are considered to be suited to make the portable radio communication apparatuses smaller in size and make the liquid crystal displays larger in size, have been spread as disclosed in the following publications.

(a) Japanese Patent Laid-open Publication No. 2001-156898;
(b) Japanese Patent Laid-open Publication No. 2002-084355;
(c) Japanese Patent Laid-open Publication No. 2002-335180;
(d) Japanese Patent Laid-open Publication No. 2002-299931; and
(e) Japanese Patent Laid-open Publication No. 2002-516503.

[0003] However, since an external antenna protrudes from the upper housing, a user often feels uncomfortable as follows. When the user takes out the portable radio communication apparatus from his pocket, the external antenna is disadvantageously got stuck in his pocket. When the user sits on the chair with the communication apparatus put in his trouser pocket, the external antenna is uncomfortably and strongly pressed onto the user. On the other hand, when the communication apparatus is suspended from the user's neck without being put into his pocket, the center of gravity of the external antenna disadvantageously deviates from the center of the communication apparatus, and the external antenna disadvantageously becomes unbalanced because of its asymmetric structure in which the external antenna is located on either the right or left end portion of the portable radio communication apparatus.

SUMMARY OF THE INVENTION

[0004] It is an object of the present invention to provide a portable radio communication apparatus, which can solve the above-mentioned disadvantages, and which can be constituted so that even if the portable radio communication apparatus is put into his pocket of a user, the user does not feel uncomfortable.

[0005] It is another object of the present invention to provide a portable radio communication apparatus, which can solve the above-mentioned disadvantages, and which can be constituted so that if the same apparatus is suspended from the user's neck, the same apparatus can be suspended in a well-balanced manner while maintaining good antenna characteristics.

[0006] According to the aspect of the present invention, there is provided a portable radio communication apparatus including a housing. The portable radio communication apparatus includes at least one part of the housing, which is formed as a housing electrical conductor portion by an electrically conductive material. The housing electrical conductor portion is connected with a radio communication circuit of the portable radio communication apparatus so as to operate as at least one part of an antenna of the radio communication circuit. A boom portion is further provided to be coupled with the housing at least at two positions so as to provide at least one penetrating hole between the housing and the boom portion.

[0007] In the above-mentioned portable radio communication apparatus, the antenna is preferably an unbalanced type antenna.

[0008] In the above-mentioned portable radio communication apparatus, the portable radio communication apparatus is preferably a straight type portable radio communication apparatus. Otherwise, the portable radio communication apparatus is preferably a slide type portable radio communication apparatus in which an upper housing and a lower housing are slidable through a sliding mechanism, and at least one part of at least one of the upper housing and the lower housing is formed as a housing electrical conductor portion by an electrically conductive material. Alternatively, the portable radio communication apparatus is preferably a folding portable radio communication apparatus in which an upper housing and a lower housing are foldable through a hinge portion, and at least one part of at least one of the upper housing and the lower housing is formed as a housing electrical conductor portion by an electrically conductive material.

[0009] In the above-mentioned portable radio communication apparatus, the housing electrical conductor portion is preferably made by forming an electrical conductor layer on a dielectric housing which is at least one part of the housing. Further, the electrical conductor layer is preferably made by forming an electrical conductor pattern on the dielectric housing.

[0010] In the above-mentioned portable radio com-

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munication apparatus, the electrical conductor layer preferably includes electrical conductor patterns different from each other on both surfaces of the dielectric housing, respectively, so that the antenna operates in a plurality of frequency bands.

[0011] In the above-mentioned portable radio communication apparatus, the electrical conductor layer preferably includes a plurality of electrical conductor portions having electric lengths different from each other, respectively, so that the antenna operates in a plurality of frequency bands.

[0012] The above-mentioned portable radio communication apparatus preferably further includes one of a slot and a slit which are formed in the electrical conductor layer.

[0013] In the above-mentioned portable radio communication apparatus, the upper housing preferably includes an upper first housing portion and an upper second housing portion, and at least one of the upper first housing portion and the upper second housing portion is formed as a housing electrical conductor portion by an electrically conductive material so that the housing electrical conductor portion operates as at least one part of the antenna of the portable radio communication apparatus.

[0014] In the above-mentioned portable radio communication apparatus, the lower housing preferably includes a lower first housing portion and a lower second housing portion, and at least one of the lower first housing portion and the lower second housing portion is formed as a housing electrical conductor portion by an electrically conductive material so that the housing electrical conductor portion operates as at least one part of the antenna of the portable radio communication apparatus.

[0015] In the above-mentioned portable radio communication apparatus, at least one part of the hinge portion preferably is formed as a hinge electrical conductor portion by an electrically conductive material, and the hinge electrical conductor portion is connected with the radio communication circuit of the portable radio communication apparatus so as to operate as at least one part of the antenna of the radio communication circuit.

[0016] In the above-mentioned portable radio communication apparatus, at least one part of the hinge portion is preferably formed as a hinge electrical conductor portion by an electrically conductive material so that the hinge electrical conductor portion operates as a parasitic element of the antenna of the radio communication circuit.

[0017] In the above-mentioned portable radio communication apparatus, the hinge portion is preferably made to be rotatable in at least biaxial directions.

[0018] The above-mentioned portable radio communication apparatus preferably further includes an electrically insulating layer formed on the hinge portion.

[0019] The above-mentioned portable radio communication apparatus preferably further includes a plurality of reactance elements having a plurality of reactance values different from each other, respectively, and a switching device for selectively switching over the plurality of reactance elements so as to connect selected one of the reactance elements with the housing electrical conductor portion.

[0020] The above-mentioned portable radio communication apparatus preferably includes a plurality of reactance elements having a plurality of reactance values different from each other, respectively, and a switching device for selectively switching over the plurality of reactance elements so as to connect selected one of the reactance elements with the housing electrical conductor portion through the hinge electrical conductor portion.

[0021] In the above-mentioned portable radio communication apparatus, the switching device preferably selectively switches over the plurality of reactance elements in accordance with whether the portable radio communication apparatus is in either one of an open state and a closed state thereof.

[0022] In the above-mentioned portable radio communication apparatus, the switching device preferably selectively switches over the plurality of reactance elements in accordance with a plurality of operating frequency bands of the portable radio communication apparatus.

[0023] In the above-mentioned portable radio communication apparatus, the switching device preferably selectively switches over the plurality of reactance elements in accordance with either one of transmission and receiving of the portable radio communication apparatus.

[0024] In the above-mentioned portable radio communication apparatus, the housing electrical conductor portion is preferably made of one of a dielectric material and a magnetic material, and the housing electrical conductor portion is connected with the radio communication circuit through an electrical insulator having a predetermined capacitance so that a radio signal from the radio communication circuit is fed through the capacitance of the electrical insulator to the housing electrical conductor portion.

[0025] The above-mentioned portable radio communication apparatus preferably further includes a thin-film-shaped electrically insulating sheet formed on the upper housing having the housing electrical conductor portion, and the thin-film-shaped electrically insulating sheet is made of one of a dielectric material and a magnetic material.

[0026] In the above-mentioned portable radio communication apparatus, the boom portion is preferably coupled with the housing so as to be laterally symmetric relative to a width direction of the portable radio communication apparatus.

[0027] In the above-mentioned portable radio communication apparatus, at least one part of the boom portion is preferably made of an electrically conductive ma-

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terial. Alternatively, at least one part of the boom portion is preferably made of a flexible dielectric material.

[0028] The above-mentioned portable radio communication apparatus preferably further includes at least one antenna element provided in the boom portion and connected with the radio communication circuit. In this case, a further switching device is further provided which selectively switches over between at least one antenna element connected with the radio communication circuit and the antenna including the housing conductor portion.

[0029] The above-mentioned portable radio communication apparatus preferably further includes a plurality of antenna elements provided in the boom portion. The plurality of antenna elements is connected with the radio communication circuit, and has electric lengths different from each other, respectively.

[0030] The above-mentioned portable radio communication apparatus preferably further includes an external antenna provided in the housing. In this case, a still further switching device is further provided which selectively switches over between the external antenna and the antenna including the housing conductor portion.

[0031] The above-mentioned portable radio communication apparatus preferably further includes a built-in antenna provided in the housing. In this case, a still further switching device is further provided which selectively switches over between the built-in antenna and the antenna including the housing conductor portion.

[0032] According to the portable radio communication apparatus of the present invention, the boom portion connected with the housing at a position where the boom portion is substantially laterally symmetric relative to the width direction of the portable radio communication apparatus. Further, there is further provided a combination of the first antenna element provided in the boom portion, and the second antenna which includes, as the constituent element, the housing whose one part is made of an electrically conductive material. It is thereby possible to transmit and receive radio waves without using any conventional external antenna. Therefore, it is possible to solve such a conventional disadvantage that the external antenna is sometimes got stuck in his pocket when the portable radio communication apparatus is taken out from his pocket. In addition, since the penetrating hole is formed in the space surrounded by the boom portion and the housing, it is possible to suspend the portable radio communication apparatus from the neck of the user with the strap attached to the boom portion. In this case, since it is unnecessary to use any conventional external antenna, the portable radio communication apparatus can be designed to be laterally symmetric, and the portable radio communication apparatus can be easily well balanced laterally when the apparatus is suspended from his neck.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] These and other objects and features of the present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings throughout which like parts are designated by like reference numerals, and in which:

Fig. 1A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a first preferred embodiment of the present invention;

Fig. 1B is a side view of the portable radio communication apparatus shown in Fig. 1A;

Fig. 1C is a plan view of an antenna element 112 employed in the portable radio communication apparatus shown in Figs. 1A and 1B;

Fig. 2 is a circuit diagram of antenna elements 102A and 901 and a radio communication circuit 110 connected with antenna elements 102A and 901 of the portable radio communication apparatus shown in Fig. 1A;

Fig. 3A is a plan view of an electrically insulating ring 201 employed in a folding portable radio communication apparatus according to a first modified preferred embodiment of the first preferred embodiment of the present invention;

Fig. 3B is a side view of the portable radio communication apparatus that includes the insulating ring 201 shown in Fig. 3A;

Fig. 4 is a circuit diagram showing an equivalent circuit of an antenna apparatus of the folding portable radio communication apparatus shown in Figs. 3A and 3B;

Fig. 5A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a second modified preferred embodiment of the first embodiment of the present invention;

Fig. 5B is a side view of the portable radio communication apparatus shown in Fig. 5A;

Fig. 6A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a third modified preferred embodiment of the first preferred embodiment of the present invention;

Fig. 6B is a side view of the portable radio communication apparatus shown in Fig. 6A;

Fig. 7A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a second preferred embodiment of the present invention;

Fig. 7B is a side view of the portable radio communication apparatus shown in Fig. 7A;

Fig. 8A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a modified preferred embodiment of

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the second preferred embodiment of the present invention;

Fig. 8B is a side view of the portable radio communication apparatus shown in Fig. 8A;

Fig. 9A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a third preferred embodiment of the present invention;

Fig. 9B is a side view of the portable radio communication apparatus shown in Fig. 9A;

Fig. 10A is a perspective view showing a hinge portion 503 for use in the portable radio communication apparatus shown in Figs. 9A and 9B;

Fig. 10B is a perspective view showing a fitting intrusive circular cylindrical member 505 connected with the hinge portion 503 shown in Fig. 10A and an antenna element 504 connected with the member 505;

Fig. 11A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a fourth preferred embodiment of the present invention;

Fig. 11B is a side view of the portable radio communication apparatus shown in Fig. 11A;

Fig. 12A is a perspective view showing a pair of hinge portions 603 and 604 employed in the portable radio communication apparatus shown in Figs. 11A and 11B;

Fig. 12B is a perspective view showing (a) a fitting intrusive circular cylindrical member 606 connected with the hinge portion 603 shown in Fig. 12A, (b) an antenna element 605 connected with the fitting intrusive circular cylindrical member 606, (c) a fitting intrusive circular cylindrical member 608 connected with the hinge portion 604 shown in Fig. 12A, and (d) an antenna element 607 connected with the fitting intrusive circular cylindrical member 608;

Fig. 13 is a circuit diagram showing a configuration of the radio communication circuit 110 connected with a hinge portion 604 of the portable radio communication apparatus shown in Figs. 11A and 11B;

Fig. 14A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a modified preferred embodiment of the fourth preferred embodiment of the present invention;

Fig. 14B is a side view of the portable radio communication apparatus shown in Fig. 14A;

Fig. 15A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a fifth preferred embodiment of the present invention;

Fig. 15B is a side view of the portable radio communication apparatus shown in Fig. 15B;

Fig. 16 is a plan view of the portable radio communication apparatus when an upper housing 702 of the portable radio communication apparatus shown in Figs. 15A and 15B is rotated counterclockwise by about 45 degrees;

Fig. 17A is a plan view of the portable radio communication apparatus shown in Figs. 15A and 15B in an open state thereof;

Fig. 17B is a side view of the portable radio communication apparatus shown in Fig. 17A;

Fig. 18 is a circuit diagram showing a configuration of the antenna elements 702A and 901 and the radio communication circuit 110 connected with the antenna elements 702A and 901 in the portable radio communication apparatus shown in Fig. 17A;

Fig. 19A is a plan view of a portable radio communication apparatus in an open state thereof according to a modified preferred embodiment of the fifth preferred embodiment of the present invention;

Fig. 19B is a side view of the portable radio communication apparatus shown in Fig. 19A;

Fig. 20 is a longitudinal sectional view showing a detailed configuration in the vicinity of a flat electrical insulator 922 shown in Fig. 19B;

Fig. 21 is a longitudinal sectional view showing a detailed configuration in the vicinity of the antenna element 921 in a further modified preferred embodiment of the portable radio communication apparatus shown in Fig. 19A;

Fig. 22A shows a first implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from an inner side surface of the upper second housing portion 102b of the portable radio communication apparatus;

Fig. 22B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 22A;

Fig. 22C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 22A;

Fig. 23A shows a second implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper first housing portion 102a of the portable ratio communication apparatus;

Fig. 23B is a plan view showing the inner side surface of the upper first housing portion 102a shown in Fig. 23A;

Fig. 23C is a plan view showing an outer side surface of the upper first housing portion 102a shown in Fig. 23A;

Fig. 24A shows a third implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable ratio communication apparatus;

Fig. 24B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 24A;

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Fig. 24C is a plan view showing the outer side surface of the upper second housing portion 102b shown in Fig. 24A;

Fig. 25A shows a fourth implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus;

Fig. 25B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 25A;

Fig. 25C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 25A;

Fig. 26A shows a fifth implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus;

Fig. 26B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 26A;

Fig. 26C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 26A;

Fig. 27A shows a sixth implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus;

Fig. 27B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 27A;

Fig. 27C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 27A;

Fig. 28A shows a seventh implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus;

Fig. 28B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 28A;

Fig. 28C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 28A;

Fig. 29A shows an eighth implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus;

Fig. 29B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 29A;

Fig. 29C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 29A

Fig. 30A shows a ninth implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus;

Fig. 30B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 30A;

Fig. 30C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 30A;

Fig. 31A shows a tenth implemental example applied to the fifth preferred embodiment of the present invention, and is a plan view showing that the upper housing 702 of the portable radio communication apparatus is detached;

Fig. 31B is a side view of the portable radio communication apparatus shown in Fig. 31A;

Fig. 32A is a plan view of the folding portable radio communication apparatus in a closed state thereof according to a sixth preferred embodiment of the present invention;

Fig. 32B is a side view of the portable radio communication apparatus shown in Fig. 32A;

Fig. 33A a plan view of the portable radio communication apparatus shown in Figs. 32A and 32B in an open state thereof;

Fig. 33B is a side view of the portable radio communication apparatus shown in Fig. 33A;

Fig. 34 is a front view which illustrate one example in which the portable radio communication apperatus shown in Fig. 32A is used while being suspended from a neck of a user;

Fig. 35A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a modified preferred embodiment of the sixth preferred embodiment of the present invention;

Fig. 35B is a side view of the portable radio communication apparatus shown in Fig. 35A;

Fig. 36A is a plan view of a folding portable radio communication apperatus in an open state thereof according to a seventh preferred embodiment of the present invention;

Fig. 36B is a side view of the portable radio communication apparatus shown in Fig. 36A;

Fig. 37A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to an eighth preferred embodiment of the present invention;

Fig. 37B is a side view of the portable radio communication apparatus shown in Fig. 37A;

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Fig. 38A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a modified preferred embodiment of the eighth preferred embodiment of the present invention;

Fig. 38B is a side view of the portable radio communication apparatus shown in Fig. 39A;

Fig. 39A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a ninth preferred embodiment of the present invention;

Fig. 39B is a side view of the portable radio communication apparatus shown in Fig. 39A;

Fig. 40A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a tenth preferred embodiment of the present invention;

Fig. 40B is a side view of the portable radio communication apparatus shown in Fig. 40A;

Fig. 41A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a modified preferred embodiment of the tenth preferred embodiment of the present invention;

Fig. 41B is a side view of the portable radio communication apparatus shown in Fig. 41A;

Fig. 42A is a plan view of a folding portable radio communication apparatus according to an eleventh preferred embodiment of the present invention;

Fig. 42B is a side view of the portable radio communication apparatus shown in Fig. 42A;

Fig. 43 is a longitudinal sectional view showing a detailed configuration of a boom portion 910 of a portable radio communication apparatus according to a further modified preferred embodiment of the preferred embodiments of the present invention;

Fig. 44A is a plan view of a slide type portable radio communication apparatus according to a twelfth preferred embodiment of the present invention;

Fig. 44B is a side view of the portable radio communication apparatus shown in Fig. 44A;

Fig. 45A is a plan view of a slide type portable radio communication apparatus according to a modified preferred embodiment of the twelfth preferred embodiment of the present invention;

Fig. 45B is a side view of the portable radio communication apparatus shown in Fig. 45A;

Fig. 46A is a plan view of a straight type portable radio communication apparatus according to a thirteenth preferred embodiment of the present invention;

Fig. 46B is a rear view of the portable radio communication apparatus shown in Fig. 46A;

Fig. 46C is a side view of the portable radio communication apparatus shown in Fig. 46A;

Fig. 47A is a plan view of a straight type portable radio communication apparatus according to a modified preferred embodiment of the thirteenth preferred embodiment of the present invention;

Fig. 47B is a rear view of the portable radio communication apparatus shown in Fig. 47A; and

Fig. 47C is a side view of the portable radio communication apparatus shown in Fig. 47A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0034] The preferred embodiments of the present invention will be described hereinafter with reference to the drawings. In the drawings, similar components are denoted by the same reference symbols, respectively.

FIRST PREFERRED EMBODIMENT

[0035] Fig. 1A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a first preferred embodiment of the present invention. Fig. 1B is a side view of the portable radio communication apparatus shown in Fig. 1A. Fig. 1C is a plan view of an antenna element 112 for use in the portable radio communication apparatus shown in Figs. 1A and 1B.

[0036] Referring to Figs. 1A and 1B, the portable radio communication apparatus according to the first preferred embodiment includes an upper housing 102 and a lower housing 103, where the housings 102 and 103 are connected with each other through a circular cylindrical uniaxial hinge portion 104, so as to be foldable through the circular cylindrical uniaxial hinge portion 104. The upper housing 102 includes an upper first housing portion 102a arranged on the inside thereof, and an upper second housing portion 102b arranged on the outside thereof. These upper first and second housing portions 102a and 102b are bonded and coupled together. A surface of the upper first housing portion 102a that opposes to the inside of the same apparatus will be referred to as an inner side surface, and a surface of the upper second housing portion 102b that opposes to the outside of the same apparatus will be referred to as an outer side surface, hereinafter. Further, the hinge portion 104 is formed integrally, for example, with the upper first housing portion 102a, is fitted into the central portion of an upper end (located between an upper left end 103p and an upper right end 103q) of the lower housing 103, and is penetrated through a circular cylindrical hollow of the circular cylindrical hinge portion 104. This leads to that the upper housing 102 and the lower housing 103 are rotatable and foldable about the hinge portion 104 by a circular cylindrical shaft (not shown) extending into the upper left end 103p and the upper right end 103q of the lower housing 103. The two housing portions 102a and 102b are penetrated into the upper first housing portion 102a from the inner side surface to the outer side surface and screwed by respective screws 113 and 114 on the left and right corner portions of the lower ends to a screw reception portion 115 of the

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upper second housing portion 102b.

[0037] At least one part of the upper first housing portion 102a is made of an electrically conductive material such as magnesium or zinc, whereas the upper second housing portion 102b is made of an electrically insulating material such as a resin material. As will be described later in detail, all of the upper first housing portion 102b may be made of an electrically conductive material. Alternatively, the upper first housing portion 102b may be made of an electrically insulating material such as a resin material with an electrical conductor layer made of an electrically conductive material formed on its surface. The portion of the upper first housing portion 102a that is formed by at least the electrically conductive material will be referred to as a conductor portion hereinafter.

[0038] Further, a liquid crystal display 105 is located substantially in the central portion of the inner side surface of the upper first housing portion 102a and a sound hole portion 106 is arranged above the liquid crystal display 105 at an upper end portion of the inner side surface of the upper first housing portion 102a. A loudspeaker 154 of Fig. 2, that generates a voice of a party on the other end of the communication line during a telephone conversation, is arranged immediately under the sound hole portion 106 so that a user of the portable radio communication apparatus can listen to the voice generated by the loudspeaker 154 through the sound hole portion 106. Further, a microphone 107 is arranged on a surface of the lower housing 103 that opposes to the inside (whose surface will be referred to as an inner side surface hereinafter) in the vicinity of a lower end on an opposite side to the hinge portion 104, and a chargeable battery 108 is arranged on a surface of the opposite side to the microphone 107 on the lower housing 103 (whose surface will be referred to as an outer side surface hereinafter). A printed wiring board 109 is arranged on the inside of the lower housing 103 and substantially in the central portion of the lower housing 103 in the thickness direction thereof. As shown in Fig. 2, a radio communication circuit 110 that includes a radio receiver 152 and a radio transmitter 153 is formed on the printed wiring board 109.

[0039] A connection point 111 that serves as a feeding point of the radio communication circuit 110 is connected with a screw 113 of the upper housing 102 through an antenna element 122, and the screw 113 is electrically connected with the conductor portion of the upper first housing portion 102a. The antenna element 122 is provided so as to extend from the radio communication circuit 110 of the lower housing 103 to the screw 113 through an inside of an upper right end of the lower housing 103, an inside of the hinge portion 104, and an inside of the upper second housing portion 102b.

[0040] As shown in Fig. 1C, an electrical conductor ring 112a having a circular hole 112h is provided on one end of the antenna element 122. The screw 113 is penetrated through the circular hole 112h, and contacted and electrically connected with the conductor ring 112a. Therefore, the connection point 111 of the radio communication circuit 110 is electrically connected with the conductor portion of the upper first housing portion 102a through the antenna element 112 and the screw 113, and then, the antenna element 112 and the conductor portion of the upper first housing portion 102a operate as a first antenna element 102A of Fig. 2 of the portable radio communication apparatus.

[0041] A boom portion 910, which is made of a resin material (preferably a flexible resin material) which is curved and generally circular cylindrical, is provided so as to be connected with left and right ends on an upper end surface of the lower housing 103. Namely, both ends of the boom portion 910 are connected with the left and right ends of the upper end surface of the lower housing 103, respectively, so as to be substantially bilaterally symmetric in the width direction or the horizontal direction of the portable radio communication apparatus. In this case, in a space surrounded by the boom portion 910 and the lower housing 103, a penetrating hole (or an air space or gap) 910h is formed. In addition, an antenna element 901 that operates as a second antenna element of the portable radio communication apparatus and that has a length such as a quarter of wavelength or the like is included in the boom portion 910. Further, the antenna element 901 is electrically connected with a connection point 902 that serves as a feeding point of the radio communication circuit 110 from an inside of the boom portion 910 through an inside of the lower housing 103.

[0042] Fig. 2 is a circuit diagram of the antenna elements 102A and 901 and the radio communication circuit 110 connected with the antenna elements 102A and 901 of the portable radio communication apparatus shown in Fig. 1A.

[0043] Referring to Fig. 2, the antenna element 102A is connected with a first terminal of a circulator 151 through the connection point 111 and a contact "a" of a switch SW1, and further, the antenna element 901 is connected thereto through the connection point 902 and a contact "b" of the switch SW1. A second terminal of the circulator 151 is connected with the radio receiver 152 that includes the loudspeaker 154 and a third terminal thereof is connected with the radio transmitter 153 that includes the microphone 107. The operations of the radio receiver 152, the radio transmitter 153, and the switch SW1 are controlled by a controller 150.

[0044] A radio signal received by the antenna element 102A or 901 is inputted to the radio receiver 152 through the switch SW1 and the circulator 151. The radio receiver 152 subjects the inputted radio signal to low noise amplification, frequency transform, a demodulation processing, thereby extracting a voice and character data and image data contained in the radio signal from the radio signal, and outputting the extracted data to the loudspeaker 154 and also to the liquid crystal display 105 to display the extracted data on the display 105. On

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the other hand, voice and character data and image data to be transmitted are inputted to the radio transmitter 153 from the microphone 107 or the controller 150. The radio transmitter 153 subjects a carrier signal to modulation, frequency transform, power amplification, and the like according to the inputted voice and character data and image data to thereby generate a radio signal, and outputs the radio signal to the antenna element 102A or 901 through the circulator 151 and the switch SW1 to project the radio signal.

[0045] The controller 150 compares, for example, a signal level of the radio signal received at the antenna element 102A with that of the radio signal received at the antenna element 901 and selectively switches over to the antenna element that receives the radio signal at the higher signal level using the switch SW1, thereby executing a reception diversity processing. Further, the controller selects one of the antenna elements based on results of the reception diversity processing to transmit the radio signal from the selected antenna element. Alternatively, by transmitting the radio signal using the both antenna elements 102A and 901 simultaneously and controlling the amplitude and the phase of the radio signal fed to the two antenna elements 102A and 901, the controller 150 may execute a transmission diversity processing.

[0046] As mentioned above, according to the first preferred embodiment, the conductor portion of the upper first housing portion 102a that is a part of the upper housing 102 is allowed to operate as a part of the antenna element 102A. Then, this leads to that the number of parts can be decreased while maintaining good antenna characteristics, and the manufacturing cost can be reduced. In addition, by forming the conductor portion of the upper first housing portion 102a using the electrically conductive material having an excellent mechanical strength such as magnesium or the like, it is possible to increase the strength of the portable radio communication apparatus against the impact such as that upon the user's dropping the same apparatus. Further, since no space occupied by an antenna apparatus is required, the portable radio communication apparatus can be made thinner and lighter in weight than the conventional apparatus. Besides, since an area of the antenna elements can be made larger than a conventional external antenna such as a helical antenna, the maximum value of a current density can be reduced and an SAR (Specific Absorption Rate) can be suppressed to be lower.

[0047] The SAR is a power absorbed by an organic structure having a unit mass when an organism such as a human is put in an electromagnetic field. The SAR is classified to a whole-body average SAR and a local SAR. The radiofrequency safety guideline specifies, for an ordinary environment (for ordinary people), that an arbitrary six-minute average of the whole-body average SAR is 0.08 W/kg or lower and the local SAR (six-minute average) for an arbitrary structure of 10 g is 2 W/kg or lower (3 W/kg for the limbs).

[0048] In the present preferred embodiment, the conductor portion of the upper first housing portion 102a is electrically connected with the antenna element 112 by the screw 113. However, the present invention is not limited to this, and they may be electrically connected with each other using the other method such as a soldering method, a crimping terminal connection method or a mechanical forced contact method without using the screw 113.

[0049] In the present preferred embodiment, the antenna element 102A is constituted by using the conductor portion of the upper first housing portion 102a and the antenna element 112. However, the present invention is not limited to this, and the antenna element 102A may be made of a feeding line such as a coaxial cable so as to feed the radio signal to the antenna element 102A through the feeding line.

[0050] In the present preferred embodiment, the portable radio communication apparatus includes the two antenna elements 102A and 901. However, the present invention is not limited to this; and the portable radio communication apparatus may not include the boom portion 910 and the antenna element 901.

[0051] In the present preferred embodiment, the circular cylindrical hinge portion 104 is employed. However, the present invention is not limited to this, and a biaxial hinge portion 704 of Fig. 15A may be employed.

[0052] In the present preferred embodiment, the boom portion 910 is connected with the lower housing 103. However, the present invention is not limited to this, and the boom portion 910 may be connected with the upper housing 102.

[0053] Fig. 3A is a plan view of an electrically insulating ring 201 employed in a folding portable radio communication apparatus according to a first modified preferred embodiment of the first preferred embodiment according to the present invention. Fig. 3B is a side view of the portable radio communication apparatus that includes the insulating ring 201 shown in Fig. 3A. Fig. 4 is a circuit diagram showing an equivalent circuit of the antenna apparatus of the folding portable radio communication apparatus shown in Figs. 3A and 3B.

[0054] In the portable radio communication apparatus shown in Figs. 1A and 1B, the antenna element 112 is screwed with the upper first housing portion 102a through the screw 113. However, the present invention is not limited to this. For example, the electrically insulating ring 201 made of a dielectric material and having a circular hole 201h shown in Fig. 3A may be inserted between the upper first housing portion 102a and an electrical conductor ring 112b (having a larger circular hole than the conductor ring 112a) of the antenna element 112 as shown in Fig. 3B, and this leads to that not only the screwing effect but also a capacitive feeding effect can be attained. As shown in Fig. 3B, the screw 113 is not mechanically contacted with the conductor ring 112b of the antenna element 112, and a capacitance

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of the insulating ring 201 is formed between the screw 113 and the antenna element 112.

[0055] Therefore, as shown in the equivalent circuit of Fig. 4, the antenna element 102A is constituted, for example, so that a plurality of inductances L1, L2, ..., and LN is connected with each other by a connection point 102Ac on one end of each inductance. The connection point 102Ac is connected with the radio transmitter 153 through an inductance LM of the screw 113, the capacitance C0 of the insulating ring 201, and an inductance L0 of the antenna element 112. Since the antenna element 102A is constituted so that the plural inductances L1, L2, ..., and LN are connected with each other at the connection point 102Ac on one end of each inductance, the portable radio communication apparatus can provide wide band characteristics. In addition, there can be obtained the following two resonance frequencies: (a) a first resonance frequency obtained when the capacitance C0 of the insulating ring 201 is inserted; and (b) a second resonance frequency, which is higher than the first resonance frequency, and which is obtained when the capacitance C0 of the insulating ring 201 is not inserted. Then, this leads to that the portable radio communication apparatus can provide wide band characteristics and operate in the two bands.

[0056] Fig. 5A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a second modified preferred embodiment of the first preferred embodiment of the present invention. Fig. 5B is a side view of the portable radio communication apparatus shown in Fig. 5A.

[0057] In the portable radio communication apparatus according to the first preferred embodiment, a thin-film-shaped electrically insulating seal 301 made of a dielectric material or a magnetic material such as acryl and having a thickness such as about 0.2 to 0.3 mm may be formed on an entire surface or a part of the inside of the upper first housing portion 102a, for example, by adhesion, as shown in Figs. 5A and 5B. This can prevent a part of a human body from directly contacting with the inner side surface of the upper first housing portion 102a that operates as the antenna element 102A, and can lower the decrease in the antenna gain caused by the human body during a telephone conversation. In addition, the distance between the antenna element 102A and the human body can be set larger, and the SAR can be kept lower. Alternatively, a transparent panel or a coating member made of a dielectric material such as a resin material may be employed instead of the insulating seal 301.

[0058] Fig. 6A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a third modified preferred embodiment of the first preferred embodiment of the present invention. Fig. 6B is a side view of the portable radio communication apparatus shown in Fig. 6A.

[0059] The portable radio communication apparatus according to the third modified preferred embodiment of the first preferred embodiment is different from that according to the first preferred embodiment shown in Figs. 1A and 1B, in that the upper first housing portion 102a is divided to a first part 102a-1 and a second part 102a-2. In this case, the first and second parts 102a-1 and 102a-2 have half the thickness of the upper first housing portion 102a, respectively, and are fitted and bonded together in the vicinity of the lower end of the upper first housing portion 102a at a position where the screw 113 is arranged. The screw 113 is screwed with the screw reception portion 115 from the inner side surface of the upper housing 102 through the second part 102a-2 and the first part 102a-1 of the upper first housing portion 102a and the upper second housing portion 102b.

SECOND PREFERRED EMBODIMENT

[0060] Fig. 7A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a second preferred embodiment of the present invention. Fig. 7B is a side view of the portable radio communication apparatus shown in Fig. 7A. The portable radio communication apparatus according to the second preferred embodiment is different from that according to the first preferred embodiment in the following points.

(a) At least one part of the upper second housing portion 102b is made of an electrically conductive material such as magnesium or zinc, and the upper first housing portion 102a is made of an electrically insulating material such as a resin material or the like. All of the upper second housing portion 102b may be made of an electrically conductive material. Alternatively, the upper second housing portion 102b may be made of an electrically insulating material such as a resin material with an electrical conductor layer made of an electrically conductive material formed on its surface. The portion of the upper second housing portion 102b that is formed by at least the electrically conductive material will be referred to as a conductor portion hereinafter.

(b) The connection point 111 that serves as a feeding point of the radio communication circuit 110 is connected with the screw 113 of the upper housing 102 through the antenna element 122, and further, the screw 113 is electrically connected with the upper second housing portion 102b of the housing 102. Therefore, the connection point 111 of the radio communication circuit 110 is electrically connected with the conductor portion of the upper second housing portion 102b through the antenna element 112 and the screw 113, and then, the antenna element 112 and the conductor portion of the upper second housing portion 102b operate as the first antenna element 102A of the portable radio communication apparatus.

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[0061] The portable radio communication apparatus constituted as mentioned above has the same functions and advantageous effects as those of the portable radio communication apparatus according to the first preferred embodiment. In addition, since the distance between the antenna element 102A and the human body can be set larger during a telephone conversation, the portable radio communication apparatus can advantageously suppress the decrease of the antenna gain caused by the electromagnetic influence of the human body. In addition, since the upper first housing portion 102a includes the liquid crystal display 105, it is necessary to secure a high strength of the upper first housing portion 102a against an impact upon the user's dropping the same apparatus. However, it is unnecessary to secure a high strength of the upper second housing portion 102b, thereby increasing the degree of freedom for designing the same apparatus.

[0062] In the present preferred embodiment, by inserting the insulating ring 201 shown in Fig. 3A between the antenna element 112 and the upper second housing portion 102b, the capacitive feeding to the antenna element 102A may be performed.

[0063] In the present preferred embodiment, the conductor portion of the upper second housing portion 102b is electrically connected with the antenna element 112 by the screw 113. However, the present invention is not limited to this, and they may be electrically connected with each other using the other method such as the soldering method, the crimping terminal connection method or the mechanical forced contact method without using the screw 113.

[0064] Fig. 8A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a modified preferred embodiment of the second preferred embodiment of the present invention. Fig. 8B is a side view of the portable radio communication apparatus shown in Fig. 8A.

[0065] The portable radio communication apparatus according to the modified preferred embodiment of the second preferred embodiment is different from that according to the second preferred embodiment shown in Figs. 7A and 7B, in that the upper second housing portion 102b is divided to a first part 102b-1 and a second part 102b-2. In this case, the first and second parts 102b-1 and 102b-2 have half the thickness of the upper second housing portion 102b, respectively, and are fitted and bonded together in the vicinity of the lower end of the upper second housing portion 102b at a position at which the screw 113 is arranged. The screw 113 is screwed with the screw reception portion 115 from the inner side surface of the upper housing 102 through the upper first housing portion 102a, the first part 102b-1 and the second part 102b-2 of the upper second housing portion 102b.

THIRD PREFERRED EMBODIMENT

[0066] Fig. 9A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a third preferred embodiment of the present invention. Fig. 9B is a side view of the portable radio communication apparatus shown in Fig. 9A. Fig. 10A is a perspective view showing a hinge portion 503 for use in the portable radio communication apparatus shown in Figs. 9A and 9B. Fig. 10B is a perspective view showing a fitting intrusive circular cylindrical member 505 connected with the hinge portion 503 shown in Fig. 10A and an antenna element 504 connected with the member 505.

[0067] The portable radio communication apparatus according to the third preferred embodiment is different from that according to the first preferred embodiment shown in Figs. 1A and 1B in the following points.

(a) The portable radio communication apparatus includes the hinge portion 503 of Fig. 10A made of an electrically conductive material such as aluminum or zinc, instead of the hinge portion 104.

(b) The portable radio communication apparatus includes the antenna element 504, and the fitting intrusive circular cylindrical member 505 which is made of an electrically conductive material such as aluminum or zinc and fitted into the hinge portion 503, instead of the antenna element 112, as shown in Figs. 9A and 9B.

[0068] Referring to Fig. 10A, the hinge portion 503 is constituted by a circular cylindrical portion 503a and two leg portions 503b and 503c extending from left and right ends of the circular cylindrical portion 503a as being inclined from an upward direction, respectively. The leg portions 503b and 503c include circular holes 503bh and 503ch, respectively, so as to penetrate them in the thickness direction thereof in the vicinity of the ends thereof. The leg portions 503b and 503c are fitted into the upper second housing portion 102b, and screws 113 and 114 are inserted into the circular holes 503bh and 503ch, respectively. Then, the leg portions 503b and 503c are screwed with the upper second housing portion 102b by the screws 113 and 114.

[0069] Referring to Fig. 10B, one end of the antenna element 504 is connected with a part of a circular cylindrical end surface of the fitting intrusive circular cylindrical member 505. The fitting intrusive circular cylindrical member 505 is formed so that an outside diameter of the member 505 is substantially equal to an inside diameter of the circular cylindrical portion 503a of the hinge portion 503, and the fitting intrusive circular cylindrical member 505 is inserted into the circular cylindrical on the inside of the circular cylindrical portion 503a, and is fitted thereinto.

[0070] In the portable radio communication apparatus constituted as mentioned above, the connection point

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111 that serves as the feeding point of the radio communication circuit 110 is electrically connected with the first upper housing portion 102a through the antenna element 504, the fitting intrusive circular cylindrical member 505, and the hinge portion 503. Therefore, the antenna element 504, the fitting intrusive circular cylindrical member 505, the hinge portion 503, and the upper first housing portion 102a can operate as the first antenna element 102A. In this case, at the connection point between the hinge portion 503 and the fitting intrusive circular cylindrical member 505 or at the connection point 111, an input impedance for the antenna is preferably low sufficiently to a predetermined impedance such as 50 Ω or the like in a predetermined frequency band such as 900 MHz or the like.

[0071] In the portable radio communication apparatus constituted as mentioned above, the antenna element 504, the hinge portion 503 and the upper first housing portion 102a operate as the first antenna element 102A. Therefore, as compared with the portable radio communication apparatus in which only the upper first housing portion 102a operates as the antenna element, the antenna apparatus can be made larger in size and the antenna gain can be thereby remarkably improved. Further, it is unnecessary to extend the antenna element 112 toward the upper housing 102 through the inside of the hinge portion 104 as shown in Fig. 1A. Therefore, a diameter of the hinge portion 104 can be made small, and the portable radio communication apparatus can be made thinner. Besides, it is possible to reduce the load on the antenna element 112 when the portable radio communication apparatus is opened or closed, and this leads to improvement of the durability of the portable radio communication apparatus.

[0072] In the present preferred embodiment, the portable radio communication apparatus may be constituted, so that, for example, the insulating ring 201 of Fig. 3A is inserted between the hinge portion 503 and the fitting intrusive circular cylindrical member 505 and then a radio signal is fed to the antenna element 102A through a capacitance.

[0073] In the present preferred embodiment, the fitting intrusive circular cylindrical member 503 is arranged in the circular cylindrical inside of the hinge portion 503. However, the present invention is not limited to this, and the antenna element 504 may be formed to extend toward the upper housing 102 as shown in Fig. 1A.

[0074] In the present preferred embodiment, the upper first housing portion 102a is employed as a part of the antenna element 102A. However, the present invention is not limited to this, and the hinge portion 503 may be electrically connected with the upper second housing portion 102b, and the upper second housing portion 102b may be employed as a component of the antenna elements 102A as shown in Fig. 7A. In this case, it is possible to set the distance between the human body and the antenna element 102A larger, and to suppress the decrease of the antenna gain caused by the electromagnetic influence of the human body during a telephone conversation.

FOURTH PREFERRED EMBODIMENT

[0075] Fig. 11A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a fourth preferred embodiment of the present invention. Fig. 11B is a side view of the portable radio communication apparatus shown in Fig. 11A. Fig. 12A is a perspective view showing a pair of hinge portions 603 and 604 employed in the portable radio communication apparatus shown in Figs. 11A and 11B. Fig. 12B is a perspective view showing (a) a fitting intrusive circular cylindrical member 606 connected with the hinge portion 603 shown in Fig. 12A, (b) an antenna element 605 connected with the fitting intrusive circular cylindrical member 606, (c) a fitting intrusive circular cylindrical member 608 connected with the hinge portion 604 shown in Fig. 12A, and (d) an antenna element 607 connected with the fitting intrusive circular cylindrical member 608. Fig. 13 is a circuit diagram showing a configuration of the radio communication circuit 110 connected with a hinge portion 604 of the portable radio communication apparatus shown in Figs. 11A and 11B.

[0076] The portable radio communication apparatus according to the fourth preferred embodiment is different from that according to the third preferred embodiment in the following points:

(a) The portable radio communication apparatus includes the hinge portions 603 and 604 made of an electrically conductive material such as magnesium or zinc, instead of the hinge portion 104.
(b) The fitting intrusive circular cylindrical member 606 which the antenna element 605 is connected with is fitted into the hinge portion 603.
(c) The fitting intrusive circular cylindrical member 608 which the antenna element 607 is connected with is fitted into the hinge portion 603.
(d) The antenna element 607 is connected with a reactance element 610 or 611 through a connection point 609 of the radio communication circuit 110. The reactance elements 610 and 611 may be variable reactance elements such as varactor diodes or the like.

[0077] Referring to Fig. 12A, the hinge portion 603 is constituted by a circular cylindrical portion 603a and a leg portion 603b, which extends from a circular cylindrical outer peripheral surface of the circular cylindrical portion 603a and has a circular hole 603h. The hinge portion 604 is constituted by a circular cylindrical portion 604a and a leg portion 604b, which extends from a circular cylindrical outer peripheral surface of the circular cylindrical portion 604a and has a circular hole 604h.

[0078] Referring to Fig. 12B, the circular cylindrical fit-

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ting intrusive member 606, which the antenna element 605 is connected with, is inserted and fitted into a circular cylindrical inside of the circular cylindrical portion 603a of the hinge portion 603, and further, the circular cylindrical fitting intrusive member 608, which the antenna element 607 is connected with, is inserted and fitted into a circular cylindrical inside of the circular cylindrical portion 604a of the hinge portion 604.

[0079] Referring to Fig. 11A, the circular cylindrical portion 603a of the hinge portion 603 is inserted and fitted between an upper left end 103p of the lower housing 103 and a protruding circular cylindrical portion 103r, and the leg portion 603b of the hinge portion 603 is inserted and fitted to the upper second housing portion 102b. Then, the screw 113 is inserted into the circular hole 603h, and this leads to that the hinge portion 603 is screwed with the upper housing 102 by the screw 113. In addition, the circular cylindrical portion 604a of the hinge portion 604 is inserted and fitted between an upper left end 103q of the lower housing 103 and the protruding circular cylindrical portion 103r, and the leg portion 604b of the hinge portion 604 is inserted and fitted to the upper second housing portion 102b. Then, the screw 114 is inserted into the circular hole 604h, and this leads to that the hinge portion 604 is screwed with the upper housing 102 by the screw 114. The connection point 111 of the radio communication circuit 110 is connected with the fitting intrusive circular cylindrical member 606 through the antenna element 605 that is provided so as to extend into the lower housing 103. The connection point 609 of the radio communication circuit 110 is connected with the fitting intrusive circular cylindrical member 608 through the antenna element 607 that is provided so as to extend into the lower housing 103.

[0080] In the portable radio communication apparatus constituted as mentioned above, the connection point 111 of the radio communication circuit 110 is electrically connected with the upper first housing 102a through the antenna element 605, the fitting intrusive circular cylindrical member 606, the hinge portion 603, and the screw 113. In addition, the connection point 609 of the radio communication circuit 110 is electrically connected with the upper first housing 102a through the antenna element 607, the fitting intrusive circular cylindrical member 608, the hinge portion 604, and the screw 114. A circuit ranging from the antenna element 605 to the upper first housing portion 102a and a circuit ranging from the antenna element 607 to the upper first housing portion 102a constitute the first antenna element 102A. In the present preferred embodiment, as shown in Fig. 13, the antenna element 102A is connected with one of reactance elements 610 and 611 respectively having reactance values Xa and Xb different from each other, through the connection point 609 and a switch SW2 controlled by a controller 150.

[0081] In addition, the fitting intrusive circular cylindrical member 606 is connected with the connection point 111 through the antenna element 605, and the fitting intrusive circular cylindrical member 608 is connected with a terminal 609a of the connection point 609 arranged on the antenna element 607. Further, a terminal 609b of the connection point 609 is connected with the first reactance element 610, and a terminal 609c thereof is connected with the second reactance element 611.

[0082] For example, when the switch SW1 of Fig. 2 is switched over to the contact "a" or the contact "b" thereof to use only the antenna element 102A as the antenna apparatus and the switch SW2 of Fig. 13 is switched over to the contact "a" or the contact "b" thereof, the reactance value of the reactance element connected with the antenna element 102A changes, and then, the resonance frequency of the antenna element 120A changes. Therefore, an operating frequency can be switched over, for example, by time division of transmission and reception. Alternatively, by switching over the switch SW2 to the contact "a" or the contact "b", for example, in accordance with the open or closed state of the portable radio communication apparatus, the reactance elements 610 and 611 may be selectively switched over. As a result, a condition of an object located in the vicinity of the antenna element 102A changes depending on whether the portable radio communication apparatus is in an open state or a closed state thereof, and then, the reactance elements 610 and 611 are selectively switched over according to the condition so as to be able to obtain a higher antenna gain.

[0083] Furthermore, when the switch SW1 of Fig. 2, for example, is switched over to the contact "b" to use only the antenna element 102A as the antenna apparatus, the antenna element 102A can operate as a parasitic element. When the switch SW2 of Fig. 13 is switched over to the contact "a" or the contact "b", the reactance value of the reactance element connected with the antenna element 102A changes. Namely, it is possible to change the electric length of the antenna element 102A that operates as a parasitic element for the antenna element 901. Therefore, it is possible to change directivity characteristics of the entire antenna apparatus.

[0084] In the present preferred embodiment shown in Fig. 13, the two reactance elements 610 and 611 are selectively switched over. However, the present invention is not limited to this, and three or more reactance elements may be selectively switched over.

[0085] In the present preferred embodiment, the first antenna element 102A is constituted by using the upper first housing portion 102a. However, the present invention is not limited to this, and the first antenna element 102A may be constituted by using the upper second housing portion 102b.

[0086] In the present preferred embodiment, the hinge portions 603 and 604 made of the electrically conductive material are employed. However, the present invention is not limited to this, and the hinge portions 603 and 604 made of a dielectric material such as a resin material or the like may be employed, and the antenna

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elements 605 and 607 may be directly and electrically connected with the upper first housing portion 102a.

[0087] Fig. 14A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a modified preferred embodiment of the fourth preferred embodiment according to the present invention. Fig. 14B is a side view of the portable radio communication apparatus shown in Fig. 14A. The portable radio communication apparatus according to the first modified preferred embodiment of the fourth preferred embodiment is different from that according to the fourth preferred embodiment by including an antenna element 612, instead of the antenna element 607 and the fitting intrusive circular cylindrical member 606.

[0088] Referring to Fig. 14A, the antenna element 612 is formed to extend into the lower housing 103, the hinge portion 603, and the upper second housing portion 102b so as to be connected with the screw 114. Therefore, the connection point 609 of the radio communication circuit 110 is electrically connected with the upper first housing portion 102a through the antenna element 612 and the screw 114. The portable radio communication apparatus according to the modified preferred embodiment of the fourth preferred embodiment constituted as mentioned above has the same functions and advantageous effects as those of the portable radio communication apparatus according to the fourth preferred embodiment.

FIFTH PREFERRED EMBODIMENT

[0089] Fig. 15A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a fifth preferred embodiment of the present invention. Fig. 15B is a side view of the portable radio communication apparatus shown in Fig. 15A. Fig. 16 is a plan view of the portable radio communication apparatus when an upper housing 702 of the portable radio communication apparatus shown in Figs. 15A and 15B is rotated counterclockwise by about 45 degrees. Fig. 17A is a plan view of the portable radio communication apparatus shown in Figs. 15A and 15B in an open state thereof, and Fig. 17B is a side view of the portable radio communication apparatus shown in Fig. 17A.

[0090] The portable radio communication apparatus according to the fifth preferred embodiment is different from that according to the first preferred embodiment in the following points.

(a) The portable radio communication apparatus includes the biaxial hinge portion 704 having a CCD camera 706 arranged in central portion thereof, instead of the uniaxial hinge portion 104. It is noted that at least one part of the biaxial hinge portion 704 is made of an electrically conductive material, and the biaxial hinge portion 704 is provided in an upper central portion of a lower housing 703.

(b) The portable radio communication apparatus includes an antenna element 802, instead of the antenna element 112.

(c) The portable radio communication apparatus includes an upper housing 702 that includes an upper first housing portion 702a and an upper second housing portion 702b, instead of the upper housing 102. The upper housing 702 includes the same components as those of the upper housing 102. In addition, in a manner similar to that of the upper first housing portion 102a, at least one part of the upper first housing portion 702a is made of an electrically conductive material, and the upper first housing portion 702a includes a conductor portion.

(d) The portable radio communication apparatus includes the lower housing 703, instead of the lower housing 103. The lower housing 703 includes the same components as those of the lower housing 702.

[0091] Referring to Figs. 15A, 15B and 16, the upper housing 702 and the lower housing 703 are connected with each other, so that they are foldable through the biaxial hinge portion 704 and the upper housing 702 is rotatable about the biaxial hinge portion 704. Referring to Fig. 16, a key pad 705 is provided almost in the central portion of an inner side surface of the lower housing 703. Referring to Figs. 17A and 17B, the antenna element 802 is provided so as to extend from the inside of the lower housing 703 toward the upper housing 702 through the inside of the biaxial hinge portion 704. A connection point 801 (corresponding to the connection point 110 shown in Figs. 1 (a) and 1(b)) that serves as a feeding point of the radio communication circuit 110 is electrically connected with an electrical conductor portion of the upper first housing portion 702a through the antenna element 802. The antenna element 802 and the upper first housing portion 702a constitute the first antenna element 702A in a manner similar to the antenna element 102A of the first preferred embodiment.

[0092] Fig. 18 is a circuit diagram showing a configuration of the antenna elements 702A and 901 and the radio communication circuit 110 connected with the antenna elements 702A and 901 of the portable radio communication apparatus shown in Fig. 17A. Referring to Fig. 18, the antenna element 702A is electrically connected with the contact "a" of the switch SW1 through the connection point 801. The other circuits are constituted in a manner similar to that of Fig. 2. Accordingly, in the present preferred embodiment, the antenna elements 702A and 901 can be selectively switched over, and the portable radio communication apparatus according to the fifth preferred embodiment has the same functions and advantageous effects as those of the portable radio communication apparatus according to the first preferred embodiment.

[0093] In the present preferred embodiment, the antenna element 802 is connected with the conductor portion of the upper first housing portion 702a. However,

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the present invention is not limited to this. At least one part of the upper second housing portion 702b may be made of an electrically conductive material and the antenna element 802 may be connected with the conductor portion of the upper second housing portion 702b. In this case, it is possible to make the distance between the human body and the antenna element 702A larger, and to suppress the decrease of the antenna gain caused by the electromagnetic influence of the human body during a telephone conversation.

[0094] Fig. 19A is a plan view of a portable radio communication apparatus in an open state thereof according to a modified preferred embodiment of the fifth preferred embodiment according to the present invention. Fig. 19B is a side view of the portable radio communication apparatus shown in Fig. 19A. Fig. 20 is a longitudinal sectional view showing a detailed configuration in the vicinity of a flat electrical insulator 922 shown in Fig. 19B.

[0095] The portable radio communication apparatus according to the modified preferred embodiment of the fifth preferred embodiment is different from that according to the fifth preferred embodiment as follows. A flat antenna element 921 is connected with a tip end of the antenna element 802, electrically connected with the conductor portion of the biaxial hinge portion 704 through the flat electrical insulator 922, and connected with the upper first housing portion 702a through the biaxial hinge portion 704. As shown in Fig. 20, the flat electrical insulator 922 is inserted between the flat antenna element 921 and the biaxial hinge portion 704 in the inside of the lower housing 703. In the portable radio communication apparatus constituted as mentioned above, a radio signal can be fed to the antenna apparatus through the capacitance in a manner similar to that of the portable radio communication apparatus shown in Fig. 3B.

[0096] Fig. 21 is a longitudinal sectional view showing a detailed configuration in the vicinity of the antenna element 921 of a further modified preferred embodiment of the portable radio communication apparatus shown in Fig. 19A. Referring to Fig. 21, the flat electrical insulator 922 shown in Fig. 20 is not employed, and the biaxial hinge portion 704 is constituted by forming an electrical conductor layer 704B on the resin housing portion 704A. In addition, the conductor layer 704B is electrically connected with the upper first housing portion 702a. By thus constituting the same apparatus, the flat antenna element 921 is electrically connected with the conductor layer 704B through the resin housing portion 704A. Therefore, in a manner similar to that of Fig. 20, in the portable radio communication apparatus, a radio signal can be fed to the antenna apparatus through the capacitance.

[0097] The various kinds of implemental examples applied to the preferred embodiments mentioned above will be next described.

[0098] Fig. 22A shows a first implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus. Fig. 22B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 22A. Fig. 22C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 22A.

[0099] Referring to Figs. 22A, 22B and 22C, an electrical conductor layer 102bm made of an electrically conductive material such as magnesium or zinc is formed on the inner side surface of a resin housing portion 102bp (including the screw reception portions 115), thereby constituting the upper second housing portion 102b, and then, for example, electrically connecting the antenna element 112 with the conductor layer 102bm. In the first implemental example constituted as mentioned above, by forming the conductor layer 102bm, the mechanical strength of the upper second housing portion 102b can be increased. In addition, since the upper housing 102 can be made of a resin material, the manufacturing cost can be reduced. Further, since a pattern of the conductor layer 102bm can be easily formed, it is possible to increase the degree of freedom for designing the antenna apparatus. Besides, since the upper second housing portion 102b is located on the opposite side of the head of an operator relative to the upper first housing portion 102a, it is possible to make the distance between the human body and the antenna element 112 larger, and to improve the antenna gain and the SAR during a telephone conversation.

[0100] Fig. 23A shows a second implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper first housing portion 102a of the portable ratio communication apparatus. Fig. 23B is a plan view showing the inner side surface of the upper first housing portion 102a shown in Fig. 23A. Fig. 23C is a plan view showing the outer side surface of the upper first housing portion 102a shown in Fig. 23A.

[0101] Referring to Figs. 23A, 23B and 23C, an electrical conductor layer 103bm made of a magnetic material such as magnesium or zinc is formed on an inner side surface of a resin housing portion 103bp (including inner peripheral surfaces of circular holes 115h on the respective screw reception portions 115 but not including the liquid crystal display 105), thereby constituting the upper first housing portion 102a, and then, for example, electrically connecting the antenna element 112 with the conductor layer 103bm. In the second implemental example constituted as mentioned above, by forming the conductor layer 103bm, the mechanical strength of the upper first housing portion 102a can be increased. In addition, since the upper housing 102 can be made of a resin material, the manufacturing cost can be reduced. Further, since a forming pattern of the conductor layer 103bm can be easily formed, it is possible to increase the degree of freedom for designing the an-

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tenna apparatus.

[0102] Fig. 24A shows a third implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus. Fig. 24B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 24A. Fig. 24C is a plan view showing the outer side surface of the upper second housing portion 102b shown in Fig. 24A.

[0103] Referring to Figs. 24A, 24B and 24C, the conductor layer 102bm made of a magnetic material such as magnesium or zinc is formed on the inner side surface of the resin housing portion 102bp (including one of the screw reception portions 115 but not including lower end portions in the vicinity of the screw reception portions 115), thereby constituting the upper second housing portion 102b, and then, for example, electrically connecting the antenna element 112 with the conductor layer 102bm. In the third implemental example constituted as mentioned above, the upper housing 102 can be electrically connected with the lower housing 103.

[0104] Fig. 25A shows a fourth implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus. Fig. 25B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 25A. Fig. 25C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 25A.

[0105] Referring to Figs. 25A, 25B and 25C, the conductor layer 102bm is made of an electrically conductive material such as magnesium or zinc, and includes a rectangular slot 931, for example, along an end portion on the left side of the inner side surface in parallel to a vertical direction of the same apparatus. The conductor layer 102bm is formed on the inner side surface of a resin housing portion 102bp (including the screw reception portions 115). This leads to constituting the upper second housing portion 102b, and then, for example, electrically connecting the antenna element 112 with the conductor layer 102bm. In the fourth implemental example constituted as mentioned above, since the slot 931 is formed on the inner side surface of the upper second housing portion 102b, an electrical conductor having a plurality of electric lengths can be formed on the conductor layer 102bm, and further, there can be realized the antenna element 102A that has a plurality of resonance frequencies and that can cover a plurality of frequency bands. Alternatively, a slit having an open end may be formed in place of the slot 931 of Figs. 25A and 25B.

[0106] Fig. 26A shows a fifth implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus. Fig. 26B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 26A. Fig. 26C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 26A.

[0107] Referring to Figs. 26A, 26B and 26C, the conductor layer 102bm is made of an electrically conductive material such as magnesium or zinc, and includes a rectangular slit 932, for example, along the end portion on the left side of the inner side surface in parallel to the vertical direction of the same apparatus and extending toward an upper end portion thereof. The conductor layer 102bm is formed on the inner side surface of a resin housing portion 102bp (including the screw reception portions 115). This leads to constituting the upper second housing portion 102b, and then, for example, electrically connecting the antenna element 112 with the conductor layer 102bm. In the fifth implemental example constituted as mentioned above, since the slit 932 is formed on the inner side surface of the upper second housing portion 102b, an electrical conductor having a plurality of electric lengths can be formed on the conductor layer 102bm, and further, there can be realized the antenna element 102A that has a plurality of resonance frequencies and that can cover a plurality of frequency bands. The slit 932 is formed to have a longitudinal length of a quarter of wavelength, and operates as a quarter-wave resonance element. Therefore, the slit 932 can be realized with half the length of the slot 931.

[0108] Fig. 27A shows a sixth implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus. Fig. 27B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 27A. Fig. 27C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 27A.

[0109] Referring to Figs. 27A, 27B and 27C, the conductor layer 102bm made of an electrically conductive material such as magnesium or zinc and including a rectangular slot 933 extending, for example, along a lower end portion of the inner side surface in parallel to a lateral or horizontal direction of the same apparatus is formed on the inner side surface of the resin housing portion 102bp (including the screw reception portions 115). This leads to constituting the upper second housing portion 102b, and then, for example, electrically connecting the antenna element 112 with the conductor layer 102bm. In the sixth implemental example constituted as mentioned above, since the slot 933 is formed on the inner side surface of the upper second housing portion 102b, an electrical conductor having a plurality of electric lengths can be formed on the conductor layer 102bm, and further, there can be realized the antenna element 102A that has a plurality of resonance frequencies and that can cover a plurality of frequency bands. Further, since the horizontal slot 933 is formed, a horizontally polarized radio wave can be projected from the

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antenna element 102A. On the other hand, since a vertically polarized radio wave is projected from the antenna element 901, polarization diversity can be constituted by using these two antenna elements.

[0110] Fig. 28A shows a seventh implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus. Fig. 28B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 28A. Fig. 28C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 28A.

[0111] Referring to Figs. 28A, 28B and 28C, the conductor layer 102bm made of an electrically conductive material such as magnesium or zinc and including an inverted-U-shaped rectangular slot 934, which is formed to extend, for example, along the lower end portion of the inner side surface in parallel to the lateral or horizontal direction of the same apparatus, and which has end portions extending downward is formed on the inner side surface of the resin housing portion 102bp (including the screw reception portions 115). This leads to constituting the upper second housing portion 102b, and then, for example, electrically connecting the antenna element 112 with the conductor layer 102bm. In the seventh implemental example constituted as mentioned above, since the slot 934 is formed on the inner side surface of the upper second housing portion 102b, an electrical conductor having a plurality of electric lengths can be formed on the conductor layer 102bm, and further, there can be realized the antenna element 102A that has a plurality of resonance frequencies and that can cover a plurality of frequency bands. Further, by changing a formation pattern of the conductor layer 102bm, the length of the slot 934 can be adjusted so as to adjust the respective resonance frequencies.

[0112] Fig. 29A shows an eighth implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus. Fig. 29B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 29A. Fig. 29C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 29A.

[0113] Referring to Figs. 29A, 29B and 29C, the conductor layer 102bm made of an electrically conductive material such as magnesium or zinc and including a rectangular slot 935 extending, for example, along the end portion on the left side of the inner side surface in parallel to the vertical direction of the same apparatus is formed on the inner side surface of the resin housing portion 102bp (including the screw reception portions 115). This leads to constituting the upper second housing portion 102b, and then, for example, electrically connecting the antenna element 112 with the conductor layer 102bm. In addition, an electrical conductor layer 102bma extending along the end portion on the left side of the outer side surface in parallel to the vertical direction is formed on the outer side surface of the upper second housing portion 102b, and this leads to formation of a parasitic element. In the eighth implemental example constituted as mentioned above, the antenna apparatus can project a radio wave through the slot 935, and further, the directivity characteristics of the antenna apparatus can be controlled using the conductor layer 102bma that serves as a parasitic element. Therefore, it is possible to project the radio wave so that the main beam thereof is directed, for example, in an opposite direction to a direction of the operator's body. Further, since the slot 935 is formed on the inner side surface of the upper second housing portion 102b, an electrical conductor having a plurality of electric lengths can be formed on the conductor layer 102bm, and further, there can be realized the antenna element 102A that has a plurality of resonance frequencies and that can cover a plurality of frequency bands.

[0114] Fig. 30A shows a ninth implemental example applied to the preferred embodiments of the present invention, and is a perspective view seen from the inner side surface of the upper second housing portion 102b of the portable radio communication apparatus. Fig. 30B is a plan view showing the inner side surface of the upper second housing portion 102b shown in Fig. 30A. Fig. 30C is a plan view showing an outer side surface of the upper second housing portion 102b shown in Fig. 30A.

[0115] Referring to Figs. 30A, 30B and 30C, rectangular electrical conductor layers 102bm1 and 102bm2 are formed on the inner side surface of the resin housing portion 102bp (including the screw reception portions 115). The rectangular electrical conductor layer 102bm1 made of an electrically conductive material such as magnesium or zinc is formed to extend, for example, along the end portion on the left side of the inner side surface in parallel to the vertical direction of the same apparatus. Further, the rectangular electrical conductor layer 102bm2 (which is different in the longitudinal length from the rectangular electrical conductor layer 102bm1) made of an electrically conductive material such as magnesium or zinc is formed to extend, for example, along the end portion on the right side of the inner side surface in parallel to the vertical direction of the same apparatus. This leads to constituting the upper second housing portion 102b, and then, for example, electrically connecting the antenna element 112 with the conductor layers 102bm1 and 102bm2. In the ninth implemental example constituted as mentioned above, since the two conductor layers 102bm1 and 102bm2 are formed on the inner side surface of the upper second housing 102b to serve a part of the antenna element 102A, an electrical conductor having a plurality of electric lengths can be formed on the antenna element 102A, and further, there can be realized the antenna element 102A that has a plurality of resonance frequencies and that can cover a plurality of frequency bands.

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Further, by changing forming patterns of the respective conductor layers 102bm1 and 102bm2, the electric length of the antenna element 102A can be adjusted so as to adjust the respective resonance frequencies.

[0116] In the ninth implemental example, the portable radio communication apparatus may be constituted to selectively switch over the antenna element of the conductor layer 102bm1 and that of the conductor layer 102bm2. For example, the portable radio communication apparatus can be constituted to selectively switch over the two antenna elements so as to be able to attain a higher antenna gain depending on whether the portable radio communication apparatus is held in the operator's right hand or left hand.

[0117] Fig. 31A shows a tenth implemental example applied to the fifth preferred embodiment of the present invention, and is a plan view showing that the upper housing 702 of the portable radio communication apparatus is detached. Fig. 31B is a side view of the portable radio communication apparatus shown in Fig. 31A.

[0118] Referring to Figs. 31A and 31B, a resin layer 704p is formed on a front surface of the biaxial hinge portion 704 made of an electrically conductive material. Namely, by forming the resin layer 704p on the portion with which the operator's head contacts during a telephone conversation, the SAR can be reduced. The resin layer 704p may be formed by using a magnetic material.

SIXTH PREFERRED EMBODIMENT

[0119] Fig. 32A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a sixth preferred embodiment of the present invention. Fig. 32B is a side view of the portable radio communication apparatus shown in Fig. 32A. Fig. 33A a plan view of the portable radio communication apparatus shown in Figs. 32A and 32B in an open state. Fig. 33B is a side view of the portable radio communication apparatus shown in Fig. 33A.

[0120] The portable radio communication apparatus according to the sixth preferred embodiment is different from that according to the first preferred embodiment by including an antenna element 211, instead of the antenna element 112. The antenna element 211 is formed to extend from the connection point 111 of the radio communication circuit 110 toward a connection point 212 on the conductor portion of the upper first housing portion 102a through the inside of the lower housing 103, the inside of the hinge portion 104, and the inside of the upper first housing portion 102a. Therefore, the connection point 111 of the radio communication circuit 110 is electrically connected with the conductor portion of the upper first housing portion 120a through the antenna element 211.

[0121] The portable radio communication apparatus according to the sixth preferred embodiment constituted as mentioned above has the same functions and advantageous effects as those of the portable radio communication apparatus according to the first preferred embodiment. In addition, since the antenna element 901 is formed on the inside of the boom portion 910 and the conductor portion of the upper first housing portion 120a operates as the antenna element 102A, the portable radio communication apparatus can transmit and receive radio waves without employing the external antenna as required in the conventional portable radio communication apparatus. Therefore, it is possible to prevent the external antenna from being got stuck with an operator's pocket when taking out the same apparatus from his pocket. Further, since the penetrating hole 910h is formed in the space surrounded by the boom portion 910 and the lower housing 103, the portable radio communication apparatus can be suspended from a neck of a user with a strap 910s attached to the boom portion 910 as shown in Fig. 34. In this case, since it is unnecessary to use the external antenna as used in the conventional portable radio communication apparatus, the portable radio communication apparatus can be designed to be laterally symmetric, and further, the portable radio communication apparatus can be easily well balanced laterally or horizontally when the same apparatus is suspended from the neck of the user.

[0122] Fig. 35A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a modified preferred embodiment of the sixth preferred embodiment of the present invention. Fig. 35B is a side view of the portable radio communication apparatus shown in Fig. 35A. The portable radio communication apparatus according to the modified preferred embodiment of the sixth preferred embodiment is different from that according to the sixth preferred embodiment, in that at least one part of the upper second housing portion 102b is made of an electrically conductive material, and in that the antenna element 211 is electrically connected with the conductor portion of the upper second housing portion 102b at the connection point 212. Namely, the antenna element 102A is constituted by using the antenna element 211 and the conductor portion of the upper second housing portion 102b. In this case, the upper first housing portion 102a may be made of either a resin material or an electrical conductive material. By thus constituting the portable radio communication apparatus, it is possible to set the distance between the antenna element 102A and the human head larger, and to suppress the decrease of the antenna gain during a telephone conversation.

[0123] In the present preferred embodiment, the antenna element 211 may be constituted by using a feeding line such as a coaxial cable.

SEVENTH PREFERRED EMBODIMENT

[0124] Fig. 36A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a seventh preferred embodiment of the present invention. Fig. 36B is a side view of the portable

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radio communication apparatus shown in Fig. 36A.

[0125] The portable radio communication apparatus according to the seventh preferred embodiment is different from that according to the third preferred embodiment, in that the fitting intrusive circular cylindrical member 505 connected with the antenna element 504 is inserted and fitted into the circular cylindrical portion of the hinge portion 104 made of an electrically conductive material which is coupled with the upper first housing portion 102a. By thus constituting the portable radio communication apparatus, the connection point 111 of the radio communication circuit 110 is electrically connected with the conductor portion of the upper first housing portion 102a through the antenna element 504, the fitting intrusive circular cylindrical member 505, and the hinge portion 104. Accordingly, the portable radio communication apparatus according to the seventh preferred embodiment has the same functions and advantageous effects as those of the portable radio communication apparatus according to the third preferred embodiment. In addition, in a manner different from that of the first preferred embodiment, it is unnecessary to extend the antenna element 504 toward the upper housing 102 through the inside of the hinge portion 104. Due to this, the thickness of the upper housing 102 can be made smaller and the diameter of the hinge portion 104 can be made smaller. Besides, the durability of the hinge portion 104 when the portable radio communication apparatus is opened or closed through the hinge portion 104 can be further improved.

[0126] In the present preferred embodiment, at least one part of the upper first housing portion 102a is made of an electrically conductive material. However, the present invention is not limited to this, and at least one part of the upper second housing portion 102b may be made of an electrically conductive material and the hinge portion 104 may be electrically connected with the upper second housing portion 102b. In this case, the antenna element 120A is constituted by using the antenna element 504, the fitting intrusive circular cylindrical member 505, the hinge portion 104, and the conductor portion of the upper second housing portion 102b. It is thereby possible to set the distance between the antenna element 102A and the human head larger during a telephone conversation, and to suppress the decrease of the antenna gain.

[0127] In the present preferred embodiment, the antenna element 504 may be constituted by using a feeding line such as a coaxial cable.

EIGHTH PREFERRED EMBODIMENT

[0128] Fig. 37A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to an eighth preferred embodiment of the present invention. Fig. 37B is a side view of the portable radio communication apparatus shown in Fig. 37A.

[0129] The portable radio communication apparatus according to the eighth preferred embodiment is different from that according to the fifth preferred embodiment shown in Fig. 17A, in that an antenna element 811 is formed to extend toward the conductor portion of the upper first housing portion 702a through the inside of the biaxial hinge portion 704, the inside of the upper second housing portion 702b, and the inside of the upper first housing portion 702a. Therefore, the connection point 801 of the radio communication circuit 110 is electrically connected with the upper first housing portion 702a at a connection point 812 through the antenna element 811. The portable radio communication apparatus according to the eighth preferred embodiment constituted as mentioned above has the same functions and advantageous effects as those of the portable radio communication apparatus according to the fifth preferred embodiment. By arranging the boom portion 910 of substantially laterally symmetric structure to be substantially laterally symmetric relative to the width direction or the horizontal direction of the portable radio communication apparatus, the design quality of the portable radio communication apparatus can be further improved. Even if the structure of the biaxial hinge portion 704 is larger, the design quality of the portable radio communication apparatus can be further improved.

[0130] The antenna element 811 can extend to be electrically insulated from the biaxial hinge portion 704, and the biaxial hinge portion 704 can operate as a parasitic element of the antenna element 102A or 901.

[0131] In the present preferred embodiment, the antenna element 811 is formed to extend into the upper first housing portion 702a and to be electrically connected with the conductor portion of the upper first housing portion 702a. However, the present invention is not limited to this, and the antenna element 811 may be connected with an electrical conductor portion of the biaxial hinge portion 704 connected with the conductor portion of the upper first housing portion 702a.

[0132] In the present preferred embodiment, the portable radio communication apparatus includes the antenna element 811. However, the present invention is not limited to this, and the portable radio communication apparatus may include the feeding line such as the coaxial cable, instead of the antenna element 811.

[0133] Fig. 38A is a plan view of a folding portable radio communication apparatus in an open state thereof according to a modified preferred embodiment of the eighth preferred embodiment of the present invention. Fig. 38B is a side view of the portable radio communication apparatus shown in Fig. 39A. The portable radio communication apparatus according to the modified preferred embodiment of the eighth preferred embodiment is different from that according to the eighth preferred embodiment, in that at least one part of the upper second housing portion 102b is made of an electrically conductive material, and in that the antenna element 811 is electrically connected with the upper second housing portion 102b. In this case, the antenna element

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102A is constituted by using the antenna element 811 and the conductor portion of the upper second housing portion 702b. It is thereby possible to set the distance between the antenna element 102A and the human head larger during a telephone conversation, and to suppress the decrease of the antenna gain.

NINTH PREFERRED EMBODIMENT

[0134] Fig. 39A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a ninth preferred embodiment of the present invention. Fig. 39B is a side view of the portable radio communication apparatus shown in Fig. 39A.

[0135] The portable radio communication apparatus according to the ninth preferred embodiment is different from the portable radio communication apparatus according to the first preferred embodiment, in that an external antenna 951 such as a quarter-wave whip antenna is provided in the vicinity of the end portion of the upper second housing portion 102b on the opposite side of the hinge portion 104 in a portable radio communication apparatus 1001, instead of the first antenna element 102A that includes the antenna element 112 and the upper first housing portion 102a. According to the portable radio communication apparatus constituted as mentioned above, by combining the external antenna 951 that has conventionally function as a main antenna in both closed and open states thereof, with the antenna element 901 (not shown in Figs. 39A and 39B) provided in the boom portion 910, then a reception diversity processing can be executed which is improved as compared with the conventional portable radio communication apparatus. In addition, the degree of freedom for designing the same apparatus to satisfy required antenna characteristics can be further improved, the external antenna 951 smaller in size than that of the conventional portable radio communication apparatus can be employed, and the design quality can be further improved.

[0136] It is noted that the installment position of the external antenna element 951 described in the present preferred embodiment is just one example, and the installment position of the external antenna element 951 is not limited to this. For example, the external antenna 951 may be arranged in the lower housing 103. In this case, the boom portion 910 may be arranged in the upper housing 102.

[0137] In the above-mentioned embodiments described, the folding portable radio communication apparatus has been described. However, the present invention is not limited to this, and a straight portable radio communication apparatus may be provided in which the external antenna 851 and the antenna element 901 of the boom portion 910 may be combined.

TENTH PREFERRED EMBODIMENT

[0138] Fig. 40A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a tenth preferred embodiment of the present invention. Fig. 40B is a side view of the portable radio communication apparatus shown in Fig. 40A.

[0139] The portable radio communication apparatus according to the tenth preferred embodiment is different from the portable radio communication apparatus according to the ninth preferred embodiment, in that a built-in antenna element 952 such as a ceramic chip antenna or the like is provided on the inside of the upper second housing portion 102b in the vicinity of the end portion of the upper second housing portion 102b on the opposite side of the hinge portion 104 of the portable radio communication apparatus, instead of the external antenna 951. In the present preferred embodiment, the built-in antenna element 952 and the antenna element 901 of the boom portion 910 (not shown in Figs. 40A and 40B) constitute the antenna apparatus. By thus constituting the portable radio communication apparatus, it is possible to improve the design quality, and to improve the degree of freedom for designing the same apparatus.

[0140] Fig. 41A is a plan view of a folding portable radio communication apparatus in a closed state thereof according to a modified preferred embodiment of the tenth preferred embodiment of the present invention. Fig. 41B is a side view of the portable radio communication apparatus shown in Fig. 41A.

[0141] The portable radio communication apparatus according to the modified preferred embodiment of the tenth preferred embodiment is different from the portable radio communication apparatus according to the tenth preferred embodiment, in that the built-in antenna element 952 is arranged on the inside of the lower housing 103 in the vicinity of the end portion of the lower housing 103 on the opposite side of the hinge portion 104. The portable radio communication apparatus according to the modified preferred embodiment of the tenth preferred embodiment has the same functions and advantageous effects as those of the portable radio communication apparatus according to the tenth preferred embodiment. As the distance between the antenna element 901 of the boom portion 910 and the built-in antenna element 952 becomes smaller, the correlation coefficient between the antenna elements 901 and 952 becomes higher by coupling between the antenna elements 901 and 952. As a result, the advantageous effects such as the diversity reception may possibly be lowered. Therefore, it is preferable that the antenna elements 901 and 952 are away from each other by at least a quarter of wavelength.

[0142] In the present preferred embodiment and the modified preferred embodiment of the tenth preferred embodiment, an instance in which the portable radio communication apparatus includes one built-in antenna element 952 has been described. However, the present invention is not limited to this, and the portable radio communication apparatus may include a plurality of

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built-in antennas. In this case, it is possible to cover a plurality of frequency bands.

ELEVENTH PREFERRED EMBODIMENT

[0143] Fig. 42A is a plan view of a folding portable radio communication apparatus according to an eleventh preferred embodiment of the present invention. Fig. 42B is a side view of the portable radio communication apparatus shown in Fig. 42A.

[0144] The portable radio communication apparatus according to the eleventh preferred embodiment is different from that according to the first preferred embodiment in the following points.

(a) The lower housing 103 is constituted so that the lower first housing portion 103a located on the inside thereof and the lower second housing portion 103b located on the outside thereof are bonded together while opposing to each other. At least one part of the lower second housing portion 103b is made of the same electrically conductive material as that of the upper first housing portion 102a of the first preferred embodiment (this portion made of an electrically conductive material will be referred to as a conductor portion hereinafter). The portable radio communication apparatus includes a key pad 116 in the central portion of the inner side surface of the lower first housing portion 103a.

(b) The portable radio communication apparatus includes the radio communication circuit 110 of the upper second housing portion 102b.

(c) The portable radio communication apparatus includes an antenna element 962 extending from the upper second housing portion 102b toward the lower second housing portion 103b through the hinge portion 104.

[0145] Referring to Figs. 42A and 42B, the antenna element 962 is provided so as to extend from a connection point 961 (corresponding to the connection point 111 shown in Fig. 1A) that serves as a feeding point of the radio communication circuit 110 into the lower first housing portion 103a through the inside of the hinge portion 104, and one end of the antenna element 962 located on the inside of the lower first housing portion 103a is connected with a screw 963.

[0146] The screw 963 penetrates the lower housing 103 from the outer side surface of the lower second housing portion 103b toward a screw reception portion 964 of the lower first housing portion 103b, and this leads to that the lower housing 103 is screwed with the screw 963 and the screw 963 is electrically connected with the conductor portion of the lower second housing portion 103b. Accordingly, the connection point 961 of the radio communication circuit 110 is electrically connected with the conductor portion of the lower second housing portion 103b through the antenna element 962 and the screw 963. As a result, the antenna apparatus is constituted by using the antenna element 962 and the conductor portion of the lower second housing portion 103b. The portable radio communication apparatus constituted as mentioned above has the same functions and advantageous effects as those of the portable radio communication apparatus according to the first preferred embodiment.

[0147] In the present preferred embodiment, the antenna element 962 is connected with the conductor portion of the lower second housing portion 103b. However, the present invention is not limited to this, and at least one part of the lower first housing portion 103a may be made of an electrically conductive material, and the antenna element 962 may be connected with the conductor portion of the lower first housing portion 103a. Alternatively, the conductor portion may be formed on each of the lower first housing portion 103a and the lower second housing portion 103b.

TWELFTH PREFERRED EMBODIMENT

[0148] Fig. 44A is a plan view of a slide type portable radio communication apparatus according to a twelfth preferred embodiment of the present invention. Fig. 44B is a side view of the portable radio communication apparatus shown in Fig. 44A.

[0149] Referring to Figs. 44A and 44B, the portable radio communication apparatus according to the present preferred embodiment includes an upper housing 102c, a lower housing 103c, and a sliding mechanism. The sliding mechanism is constituted so that two sliding protrusions 182 formed on a rear surface of the upper housing 102c are fitted into slide grooves 181 formed on both side surfaces of the lower housing 130c in a longitudinal direction thereof, respectively, and so that the upper housing 102c is slidable along the longitudinal direction thereof in a direction indicated by an arrow 183. As shown in Fig. 44A and 44B, when the upper housing 102c is located on the upper side of the sliding mechanism, a keypad 116 of the lower housing 103c appears and is made operable by the user. On the other hand, when the upper housing 102c is located on the lower side of the sliding mechanism, the keypad 116 of the lower housing 103c is covered with the upper housing 102c and is made inoperable by the user. At that time, the upper housing 102c and the lower housing 103c are integrated with each other at a minimum occupied area, and the integrated housings become similar in a form to a straight type portable radio communication apparatus which will be described later. Further, a conductor layer 103cc made of an electrically conductive material is formed on a top portion of a rear surface of the lower housing 103c, and used as an antenna element 103A. In addition, built-in antenna elements 191 and 192 each constructed by, for example, a chip antenna are included internally in left and right end portions of a lower portion of the lower housing 103c, respective-

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ly. Preferably, at least two of the three antenna elements 103A, 191, and 192 are formed, and transmission diversity and reception diversity are performed using the at least two antenna elements.

[0150] Fig. 45A is a plan view of a slide type portable radio communication apparatus according to a modified preferred embodiment of the twelfth preferred embodiment of the present invention. Fig. 45B is a side view of the portable radio communication apparatus shown in Fig. 45A.

[0151] Referring to Figs. 45A and 45B, the portable radio communication apparatus according to the present modified preferred embodiment is characterized, as compared with that of the twelfth preferred embodiment, in that the boom portion 910 including therein the antenna element 901 connected with the connection point 902 is coupled with both edges of the upper end surface of the lower housing 103c.

[0152] The characteristic constitutions of the portable radio communication apparatuses according to the first to eleventh preferred embodiments and their modified preferred embodiments may be applied to the slide type portable radio communication apparatuses according to the twelfth preferred embodiment and the modified preferred embodiment of the twelfth preferred embodiment.

THIRTEENTH PREFERRED EMBODIMENT

[0153] Fig. 46A is a plan view of a straight type portable radio communication apparatus according to the thirteenth preferred embodiment of the present invention. Fig. 46B is a rear view of the portable radio communication apparatus shown in Fig. 46A. Fig. 46C is a side view of the portable radio communication apparatus shown in Fig. 46A.

[0154] Referring to Figs. 46A, 46B, and 46C, the portable radio communication apparatus according to the present preferred embodiment is a straight type portable radio communication apparatus which includes an upper housing 102d and a lower housing 103d that are bonded to each other. For example, a conductor layer 105dc made of an electrically conductive material is formed on an upper portion of a rear surface of the lower housing 103d, and is used as the antenna element 103A. In addition, the built-in antenna elements 191 and 192 each constructed by, for example, a chip antenna are included in left and right end portions of a lower portion of the lower housing 103d, respectively. Preferably, at least two of the three antenna elements 103A, 191, and 192 are formed, and transmission diversity and reception diversity are performed using the at least two antenna elements.

[0155] Fig. 47A is a plan view of a straight type portable radio communication apparatus according to a modified preferred embodiment of the thirteenth preferred embodiment of the present invention. Fig. 47B is a rear view of the portable radio communication apparatus shown in Fig. 47A. Fig. 47C is a side view of the portable radio communication apparatus shown in Fig. 47A.

[0156] Referring to Figs. 47A, 47B and 47C, the portable radio communication apparatus according to the present modified preferred embodiment is characterized, as compared with that of the thirteenth preferred embodiment, in that the boom portion 910 including therein the antenna element 901 connected with the connection point 902 is coupled with both edges of an upper end surface of the lower housing 103d.

[0157] The characteristic constitutions of the portable radio communication apparatuses according to the first to eleventh preferred embodiments and their modified preferred embodiments may be applied to the straight type portable radio communication apparatuses according to the thirteenth preferred embodiment and the modified preferred embodiment of the thirteenth preferred embodiment.

[0158] In the above-mentioned preferred embodiments, the antenna or antenna element is preferably an unbalanced type antenna or antenna element.

MODIFIED PREFERRED EMBODIMENTS

[0159] Fig. 43 is a longitudinal sectional view showing a detailed configuration of a boom portion 910 of a portable radio communication apparatus according to a further modified preferred embodiment of the preferred embodiments of the present invention.

[0160] Referring to Fig. 43, a first electrical conductor antenna element layer 911 is formed on an upper surface of the boom portion 901, and a second electrical conductor antenna element layer 912 is formed on the lower surface of the boom portion 901 to be away from the first electrical conductor antenna element layer 911. Then, the two conductor antenna element layers 911 and 912 are electrically connected with each other at a connection point 913 in the lower housing 103, and the two conductor antenna element layers 911 and 912 are also connected with the connection point 902.

[0161] In the portable radio communication apparatus constituted as mentioned above, when the first conductor antenna element layer 911 is formed to have an electric length at which the layer 911 resonates in a lower frequency band such as 800 MHz band or the like. Further, the second conductor antenna element layer 912 is formed to have an electric length at which the layer 912 resonates in a higher frequency band such as 1.5 GHz band or the like. Then, the electric distance between the two layers 911 and 912 is smaller as the frequency becomes lower. Generally speaking, when the distance between a grounding conductor of the printed wiring board 106 in the lower housing 103, and the conductor antenna element 911 is equal to the distance between the grounding conductor thereof and the conductor antenna element 912, the antenna gain of the conductor antenna element layer in the lower frequency band is lowered. However, as shown in Fig. 43, by ar-

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ranging the conductor antenna element in the lower frequency band on the outer side (upper side) away from the grounding conductor, it is possible to set the distance of the present conductor antenna element layer to the grounding conductor of the lower housing 103 larger. The capacitive coupling between the conductor antenna element layer 911 and the grounding conductor can be remarkably reduced. Therefore, the input impedance when the antenna apparatus is viewed from the feeding point can be further lowered. It is possible to easily attain impedance matching at a predetermined characteristic impedance such as 50 Ω or the like, and it is possible to realize high antenna gain characteristics in wide bands using the two conductor antenna element layers 911 and 912.

[0162] In the preferred embodiments mentioned above, the conductor portion that operates as the antenna element 102A is formed on one of the upper first housing portion 102a and the upper second housing portion 102b. However, the present invention is not limited to this, and the conductor portion that operates as the antenna element 102A may be formed on each of the upper first housing portion 102a and the upper second housing portion 102b.

[0163] In the preferred embodiments mentioned above, the conductor portion formed on one of the upper housing 102 and the lower housing 103. However, the present invention is not limited to this, and the conductor portion may be formed on each of the upper housing 102 and the lower housing 103.

[0164] In the preferred embodiments mentioned above, the whip antenna is employed as the external antenna. However, the present invention is not limited to this, and a fixed helical antenna may be employed. Further, an inverted-F antenna may be employed as the built-in antenna. Besides, a plurality of antenna apparatuses may be provided in the upper housing 102.

[0165] In the preferred embodiments mentioned above, the upper housing 102 is connected with the lower housing 103, for example, by the antenna element 112. However, the present invention is not limited to this, and the upper housing 102 may be connected with the lower housing 103 by an electrical conductor pattern on a flexible printed wiring board.

[0166] In the preferred embodiments mentioned above, the boom portion 910 is made of an electrically conductive material such as magnesium or zinc, and this leads to that the mechanical strength of the boom portion 910 can be increased. Accordingly, even if the portable radio communication apparatus falls down to the ground, it is possible to prevent the same apparatus from being damaged. In addition, since at least one part of the boom portion 910 is formed to be filled with a dielectric material such as a resin material, it is advantageously possible to lower the resonance frequency of the antenna element 901 of the boom portion 910, and the portable radio communication apparatus can be made smaller in size as compared with the same apparatus in which the boom portion 910 is not filled with the dielectric material. Further, by fixing the surroundings of the antenna element 901 by a dielectric material such as a resin material, it is possible to increase the mechanical strengths of the boom portion 910 and the antenna element 901, and to improve the mass-producibility of the same apparatus.

[0167] In the above-mentioned preferred embodiments, at least one part of the boom portion 910 may be made of an elastic or flexible resin material such as elastomer. In this case, when the portable radio communication apparatus is put on the ground and the user pressurizes the same apparatus from above such as inadvertently stamping down the same apparatus or inadvertently dropping the same apparatus from a holding state, the impact can be absorbed and the damage of the boom portion 910 can be prevented.

[0168] In the above-mentioned preferred embodiments, the shape of the boom portion 910 is not limited to that shown in the drawings. For example, the boom portion 910 may be formed to be trapezoidal or tapered. In addition, at least one part of the boom portion 910 may be made of a transparent or semitransparent resin material. In this case, the design quality can be further improved. Further, a light emission diode that projects light during transmission of the radio wave may be arranged in the boom portion 910.

[0169] As mentioned above, according to the folding portable radio communication apparatus according to the preferred embodiments, at least one part of the upper housing or lower housing is constituted to serve as the antenna element. Therefore, it is advantageously possible to increase the strength of the same apparatus against the impact such as that upon the user's dropping the same apparatus. In addition, since it is unnecessary to secure the space occupied by the antenna element, the number of parts can be decreased, and the portable radio communication apparatus can be made thinner and lighter in weight as compared with the conventional portable radio communication apparatus. Further, by allowing the hinge portion made of the electrically conductive material to function as a part of the antenna apparatus, the antenna apparatus can be made larger in size, and the antenna gain thereof can be further improved. Additionally, by bonding the thin-film-shaped electrically insulating sheet 301 made of the dielectric material or the magnetic material onto the surface of the upper first housing portion 102a, the distance between the human body and the antenna apparatus can be set larger, and then, the decrease of the antenna gain caused by the electromagnetic influence of the human body can be suppressed during a telephone conversation.

[0170] According to the portable radio communication apparatus of the preferred embodiments mentioned above, a combination of (a) a first antenna and (b) a second antenna is provided in the vicinity of the hinge portion of the lower housing of the folding portable radio communication apparatus, where (a) the first antenna

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is the antenna element 901 of the boom portion 910 connected at a position at which the antenna element 901 is substantially laterally symmetric relative to the width direction or the horizontal direction of the same apparatus, and (b) the second antenna includes, as the component, the upper housing or lower housing at least one part of which is made of the electrically conductive material. It is thereby possible to transmit and receive radio waves without using the conventional external antenna. Therefore, it is possible to solve such a conventional disadvantages that the external antenna is sometimes get stuck with his pocket when the portable radio communication apparatus is taken out from his pocket. In addition, since the penetrating hole 910h is formed in the space surrounded by the boom portion 910 and the lower housing 103, it is possible to suspend the portable radio communication apparatus from the neck of the user with the strap 910s attached to the boom portion 910. In this case, since it is unnecessary to use any conventional external antenna, the portable radio communication apparatus can be designed to be laterally symmetric, and the portable radio communication apparatus can be easily well balanced laterally or horizontally when the same apparatus is suspended from the neck of the user.

[0171] Although the present invention has been fully described in connection with the preferred embodiments thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims unless they depart therefrom.

Claims

1. A portable radio communication apparatus comprising a housing,

   wherein at least one part of at least one of said housing is formed as a housing electrical conductor portion by an electrically conductive material,

   wherein said housing electrical conductor portion is connected with a radio communication circuit of said portable radio communication apparatus so as to operate as at least one part of an antenna of said radio communication circuit, and

   wherein said portable radio communication apparatus further comprises a boom portion coupled with said housing at least at two positions so as to provide at least one penetrating hole between said housing and said boom portion.

2. The apparatus as claimed in claim 1,

   wherein said antenna is an unbalanced type antenna.

3. The apparatus as claimed in claim 1 or 2,

   wherein said portable radio communication apparatus is a straight type portable radio communication apparatus.

4. The apparatus as claimed in claim 1 or 2,

   wherein said portable radio communication apparatus is a slide type portable radio communication apparatus in which an upper housing and a lower housing are slidable through a sliding mechanism, and

   wherein at least one part of at least one of said upper housing and said lower housing is formed as a housing electrical conductor portion by an electrically conductive material.

5. The apparatus as claimed in claim 1 or 2,

   wherein said portable radio communication apparatus is a folding portable radio communication apparatus in which an upper housing and a lower housing are foldable through a hinge portion, and

   wherein at least one part of at least one of said upper housing and said lower housing is formed as a housing electrical conductor portion by an electrically conductive material.

6. The apparatus as claimed in any one of claims 1 to 5,

   wherein said housing electrical conductor portion is made by forming an electrical conductor layer on a dielectric housing which is at least one part of said housing.

7. The apparatus as claimed in claim 6,

   wherein said electrical conductor layer is made by forming an electrical conductor pattern on said dielectric housing.

8. The apparatus as claimed in claim 6,

   wherein said electrical conductor layer includes electrical conductor patterns different from each other on both surfaces of said dielectric housing, respectively, so that said antenna operates in a plurality of frequency bands.

9. The apparatus as claimed in any one of claims 6 to 8,

   wherein said electrical conductor layer includes a plurality of electrical conductor portions having electric lengths different from each other, respectively, so that said antenna operates in a plurality of frequency bands.

10. The apparatus as claimed in any one of claims 6 to 8, further comprising one of a slot and a slit which are formed in said electrical conductor layer.

11. The apparatus as claimed in any one of claims 4 to

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10,

wherein said upper housing includes an upper first housing portion and an upper second housing portion, and

wherein at least one of said upper first housing portion and said upper second housing portion is formed as a housing electrical conductor portion by an electrically conductive material so that said housing electrical conductor portion operates as at least one part of the antenna of the portable radio communication apparatus.

12. The apparatus as claimed in any one of claims 4 to 10,

wherein said lower housing includes a lower first housing portion and a lower second housing portion, and

wherein at least one of said lower first housing portion and said lower second housing portion is formed as a housing electrical conductor portion by an electrically conductive material so that said housing electrical conductor portion operates as at least one part of the antenna of the portable radio communication apparatus.

13. The apparatus as claimed in any one of claims 5 to 12,

wherein at least one part of said hinge portion is formed as a hinge electrical conductor portion by an electrically conductive material, and

wherein said hinge electrical conductor portion is connected with the radio communication circuit of said portable radio communication apparatus so as to operate as at least one part of the antenna of said radio communication circuit.

14. The apparatus as claimed in any one of claims 5 to 12,

wherein at least one part of said hinge portion is formed as a hinge electrical conductor portion by an electrically conductive material so that said hinge electrical conductor portion operates as a parasitic element of the antenna of said radio communication circuit.

15. The apparatus as claimed in claim 13 or 14,

wherein said hinge portion is made to be rotatable in at least biaxial directions.

16. The apparatus as claimed in any one of claims 13 to 15, further comprising an electrically insulating layer formed on said hinge portion.

17. The apparatus as claimed in any one of claims 1 to 16, further comprising:

a plurality of reactance elements having a plurality of reactance values different from each other, respectively; and

a switching device for selectively switching over said plurality of reactance elements so as to connect selected one of said reactance elements with said housing electrical conductor portion.

18. The apparatus as claimed in any one of claims 13 to 16, further comprising:

a plurality of reactance elements having a plurality of reactance values different from each other, respectively; and

a switching device for selectively switching over said plurality of reactance elements so as to connect selected one of said reactance elements with said housing electrical conductor portion through said hinge electrical conductor portion.

19. The apparatus as claimed in claim 17 or 18,

wherein said switching device selectively switches over said plurality of reactance elements in accordance with whether said portable radio communication apparatus is in either one of an open state and a closed state thereof.

20. The apparatus as claimed in claim 17 or 18,

wherein said switching device selectively switches over said plurality of reactance elements in accordance with a plurality of operating frequency bands of said portable radio communication apparatus.

21. The apparatus as claimed in claim 17 or 18,

wherein said switching device selectively switches over said plurality of reactance elements in accordance with either one of transmission and receiving of said portable radio communication apparatus.

22. The apparatus as claimed in any one of claims 1 to 21,

wherein said housing electrical conductor portion is made of one of a dielectric material and a magnetic material, and

wherein said housing electrical conductor portion is connected with said radio communication circuit through an electrical insulator having a predetermined capacitance so that a radio signal from said radio communication circuit is fed through the capacitance of the electrical insulator to said housing electrical conductor portion.

23. The apparatus as claimed in any one of claims 1 to 22, further comprising a thin-film-shaped electrically insulating sheet formed on the upper housing having said housing electrical conductor portion,

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said thin-film-shaped electrically insulating sheet being made of one of a dielectric material and a magnetic material.

24. The apparatus as claimed in any one of claims 1 to 23,

wherein said boom portion is coupled with said housing so as to be laterally symmetric relative to a width direction of said portable radio communication apparatus.

25. The apparatus as claimed in any one of claims 1 to 24,

wherein at least one part of said boom portion is made of an electrically conductive material.

26. The apparatus as claimed in any one of claims 1 to 24,

wherein at least one part of said boom portion is made of a flexible dielectric material.

27. The apparatus as claimed in any one of claims 1 to 26, further comprising at least one antenna element provided in said boom portion and connected with said radio communication circuit.

28. The apparatus as claimed in claim 27, further comprising a further switching device for selectively switching over between at least one antenna element connected with said radio communication circuit and said antenna including said housing conductor portion.

29. The apparatus as claimed in any one of claims 1 to 26, further comprising a plurality of antenna elements provided in said boom portion, said plurality of antenna elements being connected with said radio communication circuit, and having electric lengths different from each other, respectively.

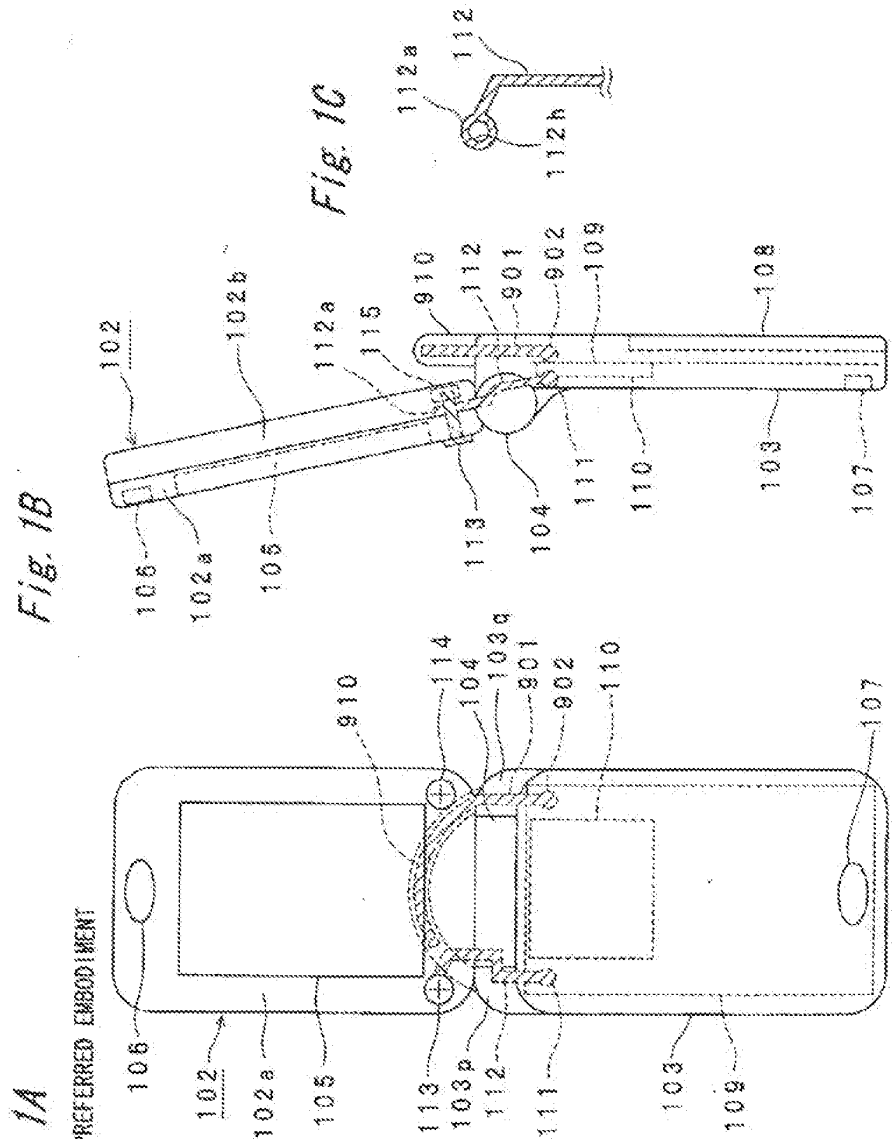
30. The apparatus as claimed in any one of claims 1 to 28, further comprising an external antenna provided in said housing.

31. The apparatus as claimed in claim 30, further comprising a still further switching device for selectively switching over between said external antenna and the antenna including said housing conductor portion.

32. The apparatus as claimed in any one of claims 1 to 28, further comprising a built-in antenna provided in said housing.

33. The apparatus as claimed in claim 32, further comprising a still further switching device for selectively switching over between said built-in antenna and the antenna including said housing conductor portion.

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Fig. 2

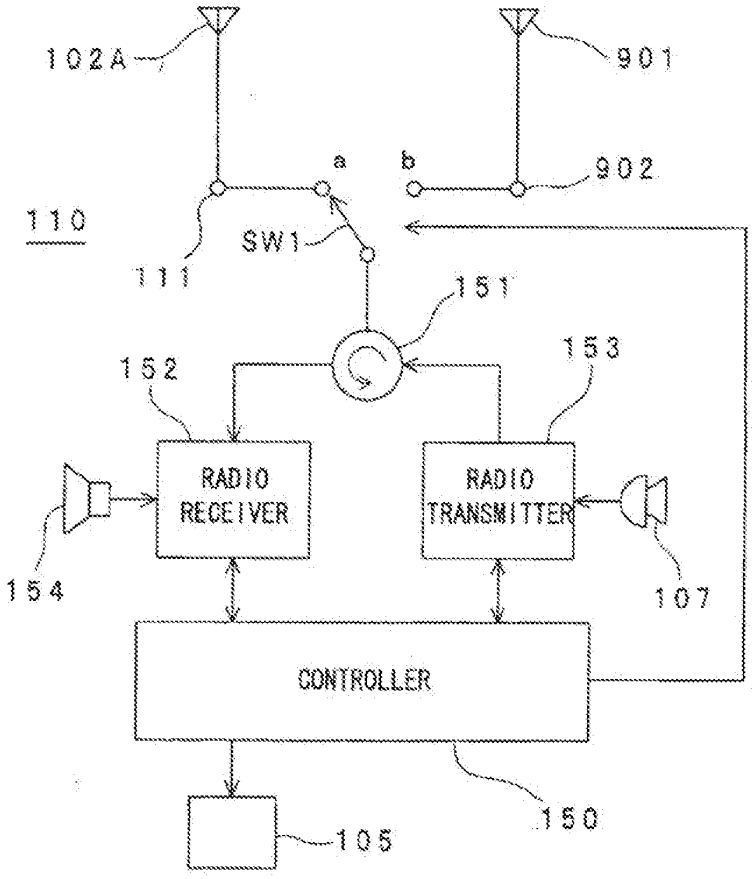

102A
901
a
b
902
110
SW1
111
151
152
153
RADIO RECEIVER
RADIO TRANSMITTER
154
107
CONTROLLER
150
105

Fig. 3B

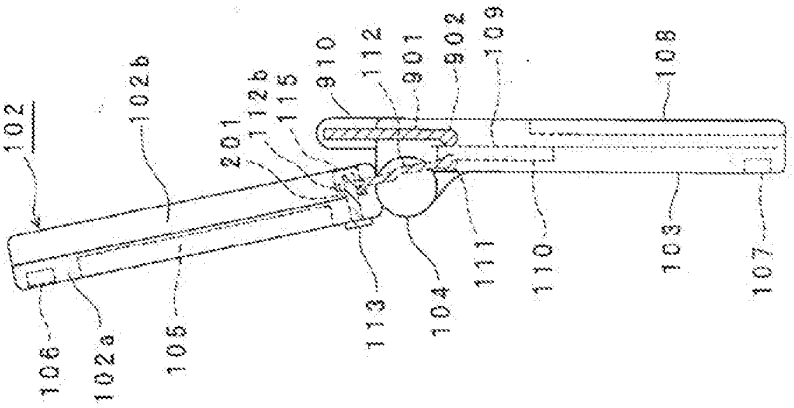


Fig. 3A

FIRST MODIFIED PREFERRED EMBODIMENT
OF FIRST PREFERRED EMBODIMENT

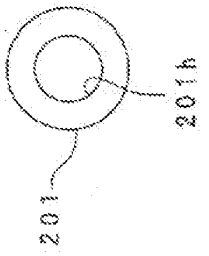
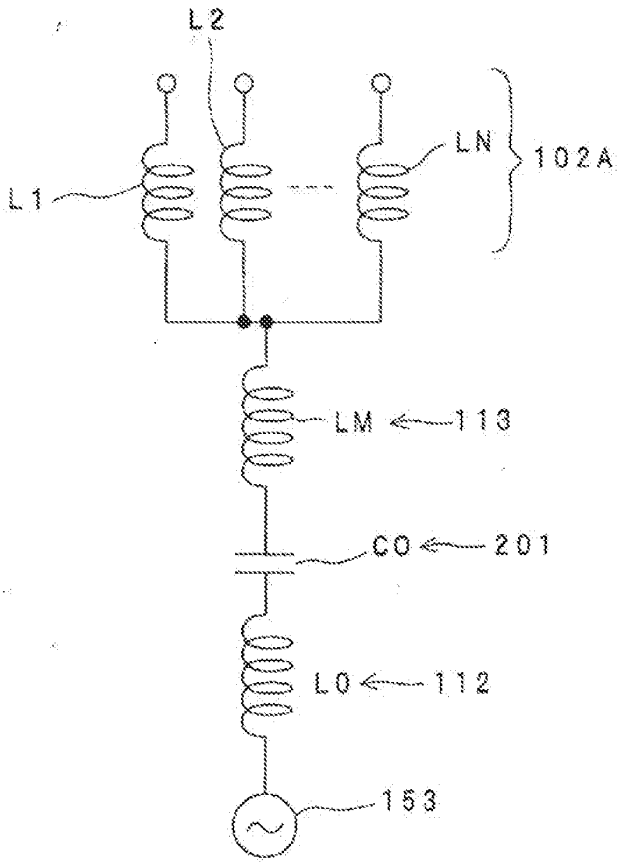


Fig. 4



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Fig. 5A

SECOND MODIFIED PREFERRED EMBODIMENT OF FIRST PREFERRED EMBODIMENT

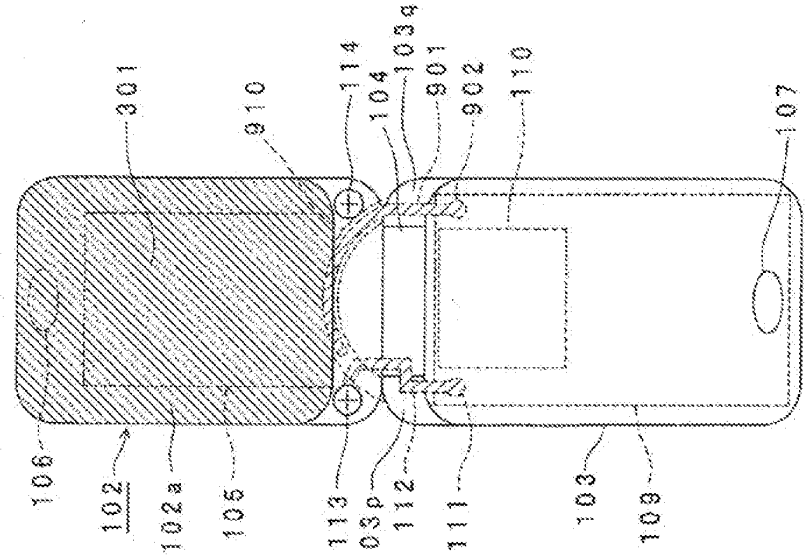
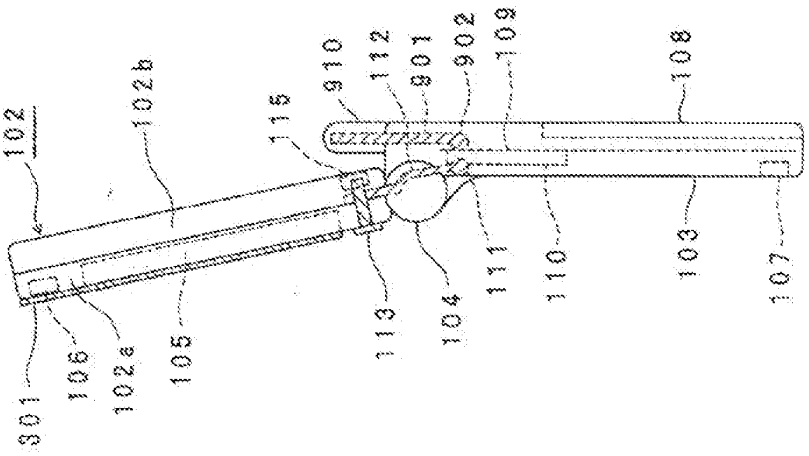


Fig. 5B



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Fig. 6A

THIRD MODIFIED PREFERRED EMBODIMENT
OF FIRST PREFERRED EMBODIMENT

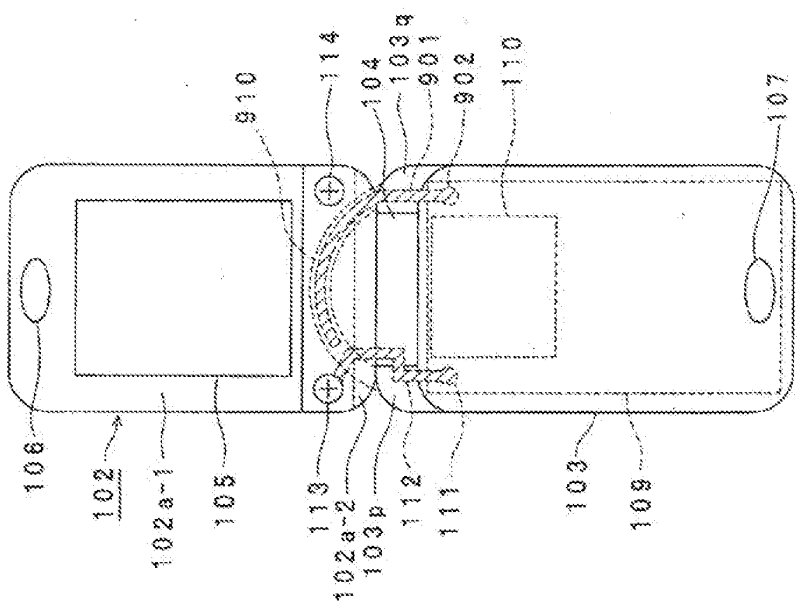


Fig. 6B

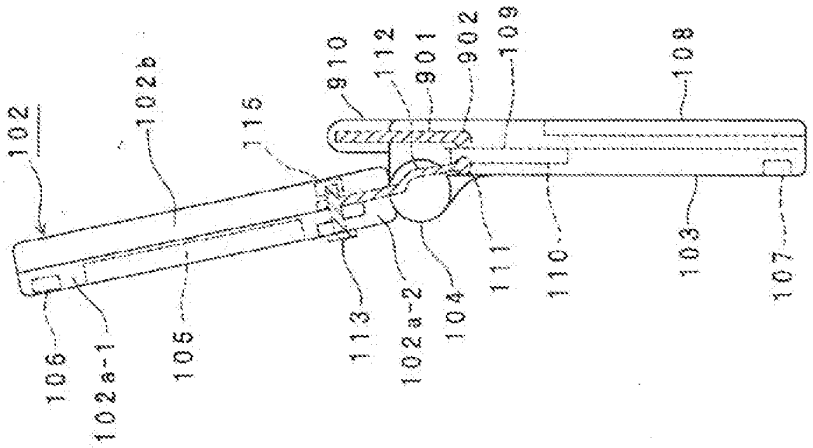


Fig. 7B

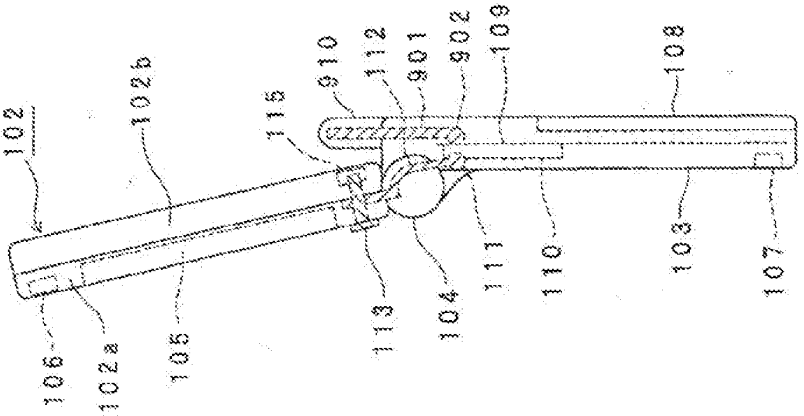
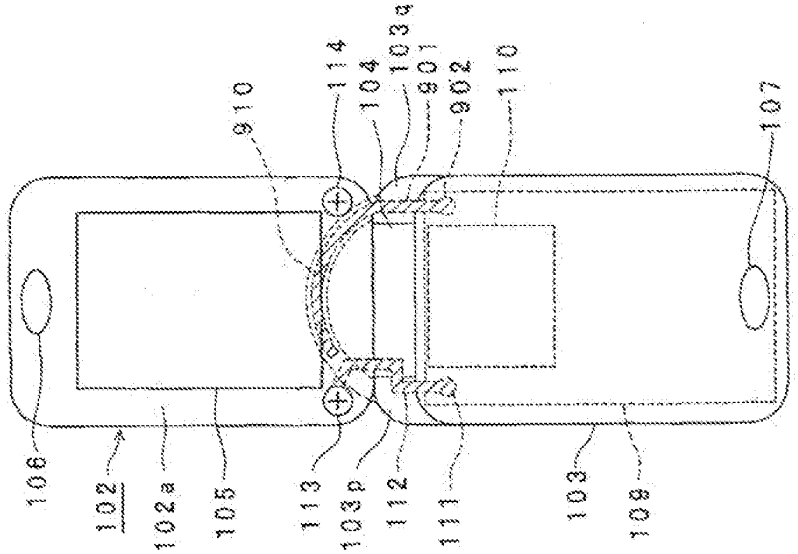


Fig. 7A

SECOND PREFERRED EMBODIMENT



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Fig. 8A

MODIFIED PREFERRED EMBODIMENT OF SECOND PREFERRED EMBODIMENT

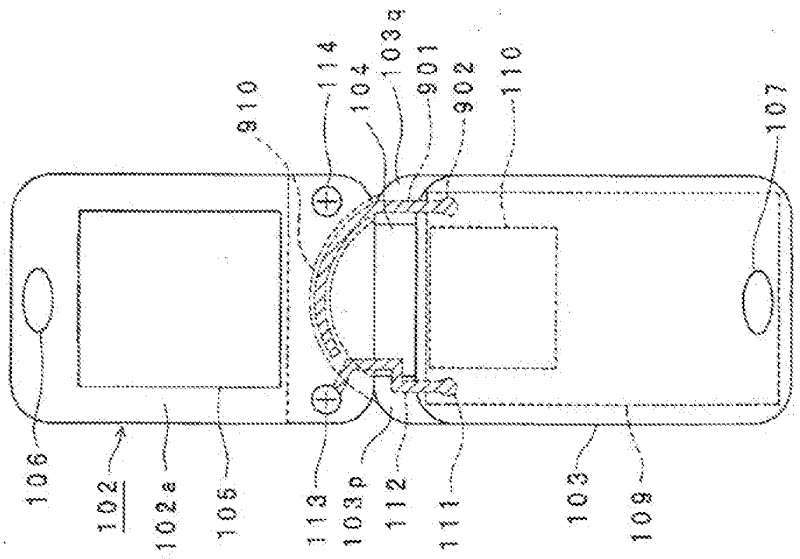
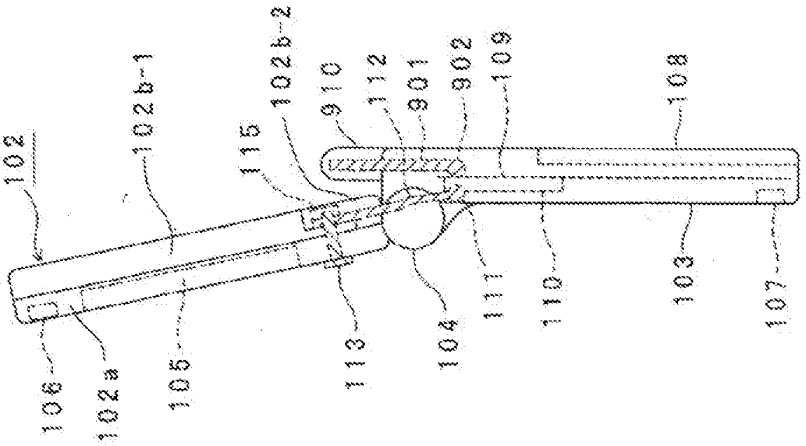


Fig. 8B



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Fig. 9B

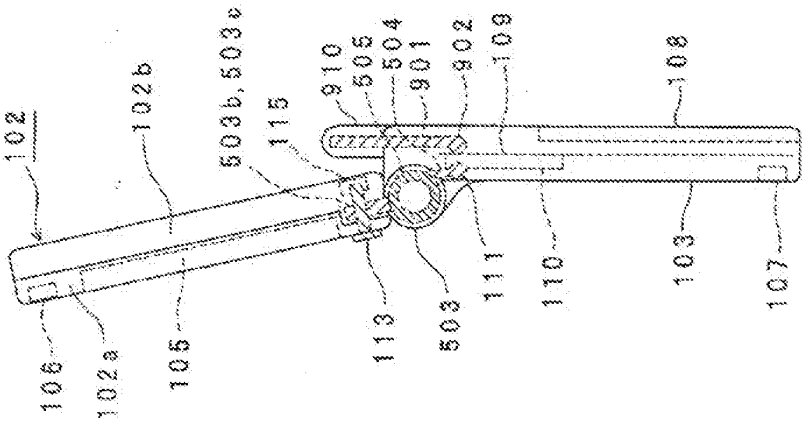
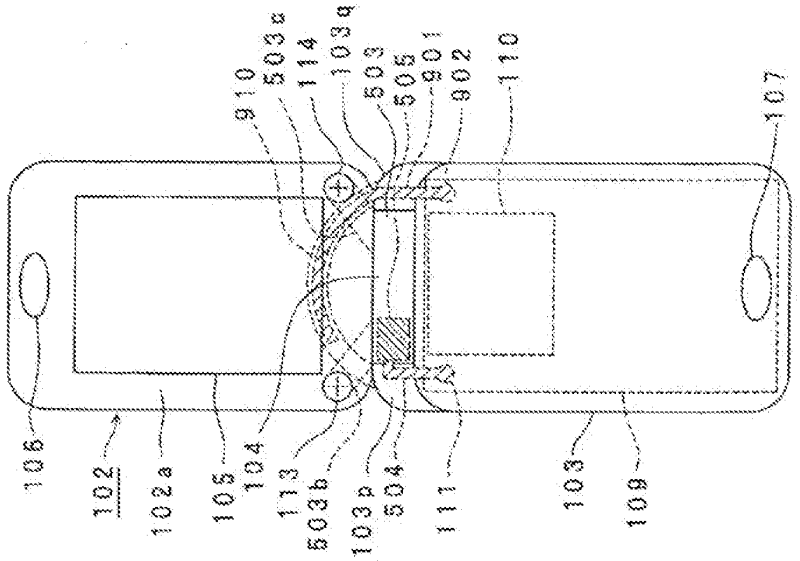


Fig. 9A

THIRD PREFERRED EMBODIMENT



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

(11) EP 1 401 050 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
24.03.2004 Bulletin 2004/13

(51) Int Cl.7: **H01Q 9/04**, H01Q 1/24, H01Q 5/00, H01Q 1/48

(21) Application number: **03396086.5**

(22) Date of filing: **17.09.2003**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR
Designated Extension States:
AL LT LV MK

(30) Priority: **19.09.2002 FI 20021668**

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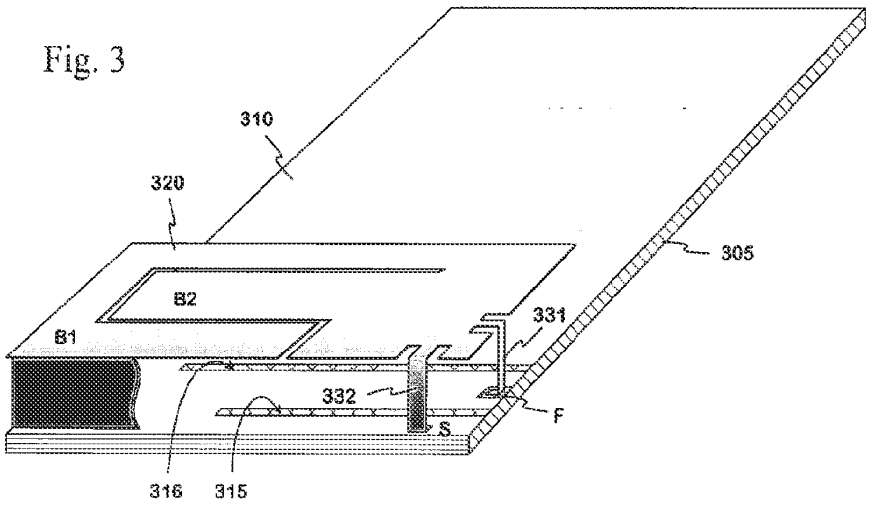
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(54) Internal antenna

(57) An internal planar antenna for small radio apparatuses, and a radio apparatus. The ground plane (310) of the planar antenna is shaped such that it improves the matching of the antenna. The shaping may be done by means of one or more slots (315, 316) in the ground plane. The slot suitably changes the electrical length of the ground plane as viewed from the short-circuit point (S) so that the ground plane will function as a radiator in an operating band of the antenna. Also the slot (331) in the ground plane can be arranged to function as an additional radiator in an operating band of the antenna. Antenna gain will increase as the matching is improved, and the upper band of a dual band antenna, for example, can be made broader. Alternatively, the antenna can be fabricated flatter without degrading the electrical characteristics.

Fig. 3



EP 1 401 050 A1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] The invention relates to an internal planar antenna intended for small radio apparatuses. The invention also relates to a radio apparatus employing an antenna according to the invention.

[0002] In antenna design, the space available is an important factor. A good-quality antenna is relatively easy to make if there are no size restrictions. In radio apparatuses, especially in mobile phones, the antenna is preferably placed within the covering of the device for convenience. As the devices get smaller and smaller, the space for the antenna keeps shrinking, too, which means tighter requirements in antenna design. Another factor contributing to this is that often an antenna has to be capable of operating in two or more frequency bands.

[0003] An antenna with satisfactory characteristics which fits inside a small device is in practice most easily implemented as a planar structure: The antenna comprises a radiating plane and a ground plane parallel thereto. In order to make impedance matching easier, the radiating plane and ground plane are usually interconnected at a suitable point by means of a short-circuit conductor, producing a PIFA (planar inverted F antenna) type structure. The size of the ground plane naturally has significance as regards the antenna characteristics. As in the case of a monopole whip, an ideal planar antenna also has a very large ground plane. As the ground plane gets smaller, the resonances of the antenna get weaker and, partly for that reason, the antenna gain decreases. If one keeps on reducing the size of the ground plane, it may at some point function as a radiator, thus changing the antenna characteristics in an uncontrolled manner.

[0004] Fig. 1 shows a known PIFA-type internal planar antenna. It includes a circuit board 105 of the radio apparatus, which board has a conductive upper surface. That conductive surface functions as a ground plane 110 for the planar antenna. At the other end of the circuit board there is a radiating plane 120 of the antenna, supported above the ground plane by a dielectric frame 150. The antenna structure further comprises, near a corner of the radiating plane, an antenna feed conductor 131 joining thereto, and a short-circuit conductor 132 connecting the radiating plane to the ground plane at a point S. From the feed conductor there is a via hole, isolated from the ground, to an antenna port on the lower surface of the circuit board 105. In the radiating plane there is a slot 125 which starts from an edge of the plane near the feed conductor 131 and ends up in the inner region of the plane near the opposite edge. The slot 125 divides the radiating plane, viewed from the short-circuit point, into two branches B1, B2 of different lengths. The PIFA thus has two separate resonance frequencies and respective operating bands.

[0005] A disadvantage of the antenna of Fig. 1, when the radio apparatus in question is very small, is that it has somewhat modest electrical characteristics. This is caused by the smallness of the ground plane, as described above, and also by the limited height of the antenna, as the radio apparatus is made relatively flat.

[0006] An object of the invention is to reduce said disadvantage associated with the prior art. An antenna according to the invention is characterized in that which is specified in the independent claim 1. A radio apparatus according to the invention is characterized in that which is specified in the independent claim 12. Some preferred embodiments of the invention are presented in the dependent claims.

[0007] The basic idea of the invention is as follows: The ground plane of a planar antenna in a small radio apparatus is shaped such that antenna's electrical performance improves. The shaping can be done by making a slot or several slots in the ground plane. The slot changes the electrical length of the ground plane, as viewed from the short-circuit point, so that the ground plane will better function as a radiator in an operating band of the antenna. The slot in the ground plane may also be arranged to serve as an additional radiator in an operating band of the antenna.

[0008] An advantage of the invention is that the antenna gain will increase as the matching improves, compared to a corresponding antenna according to the prior art. Thus it is possible, for example, to shorten the distance between the ground plane and the radiating plane proper by an amount corresponding to the antenna gain difference. This will result in an antenna having the same antenna gain but which is flatter, which is advantageous in small radio apparatuses. Another advantage of the invention is that the upper band of a dual-band antenna, for example, can be made wider. This is accomplished by suitably offsetting the resonance frequency of the slot radiator in the ground plane from the resonance frequency of the radiator proper. A further advantage of the invention is that the arrangement according to the invention is very simple.

[0009] The invention is below described in detail. The description refers to the accompanying drawings where

- Fig. 1 shows an example of a planar antenna according to the prior art,
- Fig. 2a shows an example of the ground plane of a planar antenna according to the prior art,
- Fig. 2b shows an example of the ground plane of a planar antenna according to the invention,
- Fig. 3 shows an example of the planar antenna according to the invention,
- Fig. 4 shows the ground plane of the antenna illustrated in Fig. 3,
- Fig. 5 shows an example of using a discrete capacitor in ground plane,

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Fig. 6 shows a fourth example of the ground plane according to the invention,

Fig. 7 shows a fifth example of the ground plane according to the invention,

Fig. 8 shows an example of how the invention influences antenna matching,

Fig. 9 shows an example of how the invention influences antenna gain,

Fig. 10 shows an example of a radio apparatus equipped with an antenna according to the invention.

[0010] Fig. 1 was already discussed in conjunction with the description of the prior art.

[0011] Figs. 2a,b illustrate the principle of increasing the electrical length of the ground plane in accordance with the invention. Fig. 2a shows the circuit board 105 of the structure depicted in Fig. 1 as seen from the ground plane's side. At the upper left corner of the ground plane 110 there is the short-circuit point **S** for the radiating plane. As the ground plane has no patterns altering its shape, its electrical length, measured from the short-circuit point, is determined by the lengths of the sides of the rectangular plane. As the ground plane is relatively small, its electrical length is significant, because the ground plane may radiate at a frequency order of operating frequencies, like a branch of a dipole antenna.

[0012] Fig. 2b shows a printed circuit board 205 which is similar to the one described above except that there is now a slot 215 in the ground plane. The slot starts from the long side of the ground plane near the short-circuit point **S** and travels parallel to the short side of the ground plane beyond the half-way point of the short side in this example. The slot 215 increases the electrical length because now the ground plane currents have to turn around the closed end of the slot. The broken line 219 starting from the short-circuit point approximately illustrates the electrical length of the ground plane. The electrical length can be arranged e.g. such that the ground plane improves the matching of a dual-band antenna in the lower band.

[0013] Fig. 3 shows an example of a whole planar antenna according to the invention. It includes a circuit board 305 of a radio apparatus, where the conductive upper surface of the board functions as a ground plane for the planar antenna. At one end of the circuit board, above the board, there is, from the point of outline, a rectangular-shaped radiating plane 320 of the antenna, with two branches B1 and B2 of different lengths to produce two operating bands, like in Fig. 1. Near a corner of the radiating plane, a short-circuit conductor 332 extends from a long side of the radiating plane to the ground plane, which long side is parallel to a short side of the ground plane. The ground plane has a first slot 315 according to the invention, like slot 215 in Fig. 2, which first slot is located near the short-circuit point of the antenna, parallel to the short side of the ground plane. The feedline conductor 331 of the antenna joins to the radiating plane near the same corner as the short-circuit conductor, but in this example on the side of the short side of the radiating plane such that the first slot 315 goes between the short-circuit point **S** and feed point **F** marked on the circuit board. This arrangement makes possible to place the first slot 315 closer to the short side of the ground plane than what would be possible if the feed point with its via hole were on the same side, like in Fig. 1.

[0014] The example of Fig. 3 further shows a second slot 316 according to the invention. This one starts from the same long side of the ground plane and travels parallel to the first slot. In this example the feed point **F** lies between the first and second slots on the surface of the circuit board 305. The first 315 and second 316 slots as well as the feed point **F** and short-circuit point **S** can be better seen in **Fig. 4** illustrating the circuit board 305 of the structure depicted in Fig. 3, as viewed from the ground plane side. The placement and length of the second slot 316 can be such that resonance is excited in the slot in the upper operating band of the antenna. Thus it functions as a slot radiator, improving the matching in the upper operating band. Similarly, in the single-slot case according to Fig. 2, the slot can be tuned so as to function as a radiator in the upper operating band.

[0015] As an additional way reactive discrete components can be used in the ground plane arrangement. **Fig. 5** shows an example of such an arrangement. It includes a circuit board 505 of a radio apparatus where the ground plane of the board has two slots according to the invention, like in Fig. 4. Across the second slot 516, near its open end, there is connected a capacitor **C**. The capacitance thereof decreases the electrical length of the ground plane, e.g. in the case of a dual-band antenna, naturally more significantly in the upper operating band than in the lower. If the slots 515, 516 in the ground plane are dimensioned so as to improve antenna characteristics in the lower operating band, the capacitor can then be used to prevent antenna characteristics from worsening in the upper operating band for the reason mentioned above. On the other hand, if the second slot is used as a radiator, the capacitor helps produce a slot with a desired electrical length, physically shorter than what it would be without a capacitor. A suitable capacitance for the capacitor in an arrangement according to Fig. 5 and in the gigahertz region is on the order of 1 pF.

[0016] Fig. 6 shows a fourth example of ground plane design according to the invention. In this case, too, the ground plane has two slots according to the invention. A first slot 615 travels between the short-circuit point **S** and feed point **F**, having a rectangular bend at the end thereof. A second slot 616 is now located lower in the

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ground plane, starting from a long side of the ground plane opposite to that long side at which the short-circuit and feed points are located. The first slot can be dimensioned so as to function as a radiator in the upper operating band of the antenna, and the second slot 616 can be dimensioned so as to improve antenna matching in the lower operating band by increasing the electrical length of the ground plane.

[0017] Fig. 7 shows a fifth example of ground plane design according to the invention. In this case the ground plane has one slot 715 according to the invention. The feed point **F** is close to a corner of the circuit board 705, and the short-circuit point **S** is located more centrally in the direction of the short side of the board. The slot 715 starts from the edge of the ground plane at the short side of the circuit board, travels between the feed point and short-circuit point, and then turns parallel to the short side of the board, extending near the opposite long side of the circuit board. When propagating in the ground plane from the short-circuit point on, it is necessary to turn around the closed end of the slot 715, which means an increase in the electrical length of the ground plane. The difference to the structure of Fig. 2b is that the feed and short-circuit points are now placed on different sides of the slot in the ground plane. This can be utilized when using the slot 715 as a radiator.

[0018] Fig. 8 illustrates the effect of the invention on antenna matching in an example case. The quality of the matching is represented by the measured values of the reflection coefficient S11. Curve 81 illustrates the variation in the reflection coefficient of a prior-art dual-band antenna as a function of frequency, and curve 82 the variation of a corresponding antenna according to the invention which has two slots in the ground plane as depicted in Fig. 3. Comparing the curves, one can see that in the upper band, in the 1.9 GHz region, the best value of the reflection coefficient improves from -8 dB to about -13 dB, i.e. approximately by 5 dB. At the same time, the bandwidth B increases from about 150 MHz to about 200 MHz, using reflection coefficient value -6 dB as a criterion. In the lower band in the 0.9 GHz region the best value of the reflection coefficient improves by over 2.5 dB, i.e. from - 11 dB to about -13.5 dB. At the same time the bandwidth increases perceptibly.

[0019] Fig. 9 illustrates the effect of the invention on antenna gain. Antenna gain is here computed using a simulation model. Curve 91 illustrates the variation in the antenna gain G_{max} of a prior art dual band antenna as a function of frequency, computed in the most advantageous direction, and curve 92 the variation in the antenna gain G_{max} of a corresponding antenna according to the invention which has two slots in the ground plane as depicted in Fig. 3, computed in the most advantageous direction. Comparing the curves, one can see that in the upper band the antenna gain is improved from about 3 dB to about 4 dB, i.e. approximately by one decibel. Antenna gain is also improved in the lower operating band in the 0.9 GHz region. The increase is a little over a half decibel.

[0020] As was mentioned earlier, the improvements brought about by the invention in the electrical characteristics can be utilized by reducing the distance between the ground plane and radiating plane proper by an amount corresponding to the antenna gain difference. If the increase of about 30 % in the bandwidth of the upper operating band and the one-decibel increase in antenna gain are lost in this manner, one will get a planar antenna which is about 40% flatter.

[0021] Fig. 10 shows a radio apparatus RA equipped with an internal planar antenna according to the invention. The antenna comprises a ground plane on the circuit board 005 of the radio apparatus, and a radiating plane 020 at that end of the circuit board which in the figure is the upper end. The ground plane has at least one slot which has an improving effect on antenna matching.

[0022] The words "lower" and "upper" and "above" refer in this description and in the claims to the positions of the antenna structure and its ground plane as depicted in Figs. 1 to 7, and they are in no way connected to the operational position of the antenna. Likewise, mentions about the "short" and "long" sides of the structural parts refer in this description and in the claims to the dimensions depicted in Figs. 1 to 7 and do not restrict the actual dimensions.

[0023] Some antenna structures according to the invention were described above. The invention does not limit the shapes of the antenna elements to those just described. Nor does the invention limit the fabricating method of the antenna or the materials used therein. The inventional idea can be applied in different ways within the scope defined by the independent claim 1.

Claims

1. An internal planar antenna for a radio apparatus, having a ground plane, radiating plane, a feed conductor for the latter, and a short-circuit conductor which connects the radiating plane to the ground plane at a short-circuit point (S), **characterized in that** the ground plane (210; 310) has at least one non-conductive slot (215; 315, 316; 415, 416) starting from an edge thereof in order to improve the matching of the antenna.

2. An antenna according to claim 1 the ground plane of which is a conductive layer on the upper surface of a circuit board in the radio apparatus and the radiating plane of which is a conductive plane above the ground plane and has an outline shaped substantially like a rectangle, **characterized in that** the short-circuit point (S) is located relatively close, in proportion to the lengths of the sides of the radiating plane (320), to a projection of a corner of the radiating plane in the circuit board, and said slot (215;

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315; 515; 615) in the ground plane starts from the edge of the ground plane, relatively near the short-circuit point and travels substantially parallel to a long side of the radiating plane.

3. An antenna according to claim 2, **characterized in that** said slot (215; 315; 515; 615; 715) in the ground plane increases the physical length of the ground plane as measured from the short-circuit point.

4. An antenna according to claim 1 having at least two operating bands, **characterized in that** there are two of said slots in the ground plane, a first (315; 515; 615) and a second slot (316; 516; 616).

5. An antenna according to claims 3 and 4 in which the feedline conductor for the radiating plane travels through said circuit board at a feed point (F), **characterized in that** said second slot (316; 516) starts from the same side of the ground plane as the first slot (315; 515) depicted in claim 2, traveling substantially parallel to the first slot, and said feed point lies between the first and second slots on the circuit board.

6. An antenna according to claim 1, **characterized in that** it further comprises a capacitor (C) which is connected across said slot in the ground plane.

7. An antenna according to claim 5 and 6, **characterized in that** the slot in the ground plane, across which the capacitor is connected, is the second slot (516).

8. An antenna according to claim 1 having at least a lower and an upper operating band, **characterized in that** said slot in the ground plane is arranged so as to resonate in the upper operating band of the antenna.

9. An antenna according to claims 5 and 8, **characterized in that** the slot arranged to resonate in the upper operating band of the antenna is the second slot (316).

10. An antenna according to claims 4 and 8, **characterized in that** said second slot (616) starts from a side of the ground plane which is opposite to that side from which the first slot (615) starts, the second slot increases the physical length of the ground plane as measured from the short-circuit point, and the first slot is arranged to resonate in the upper operating band of the antenna.

11. An antenna according to claim 4, **characterized in that** at least one slot (415; 715) in the ground plane includes a portion the direction of which differs substantially from the direction of said long side of the radiating plane.

12. A radio apparatus (RA) with an internal planar antenna comprising a ground plane on a circuit board, a radiating plane (720), a feed conductor for the latter, and a short-circuit conductor which connects the radiating plane with the ground plane at a short-circuit point, **characterized in that** the ground plane has at least one non-conductive slot starting from an edge thereof in order to improve the matching of the antenna.

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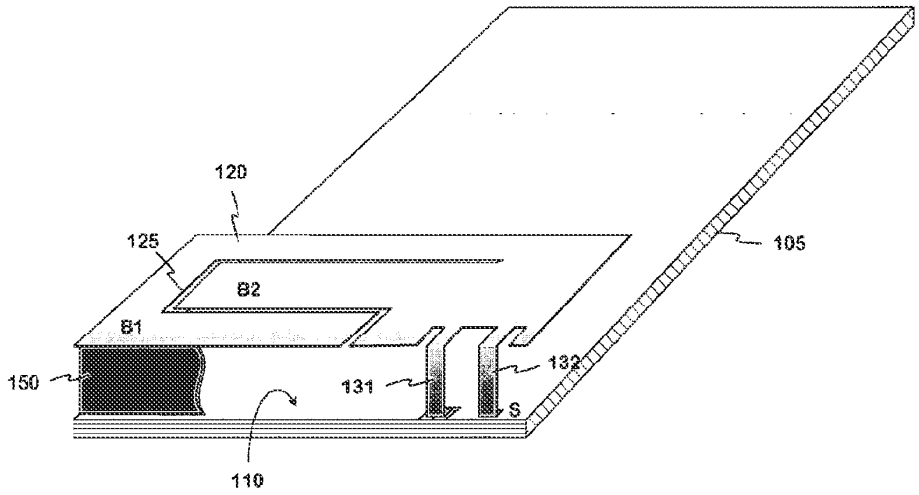


Fig. 1 PRIOR ART

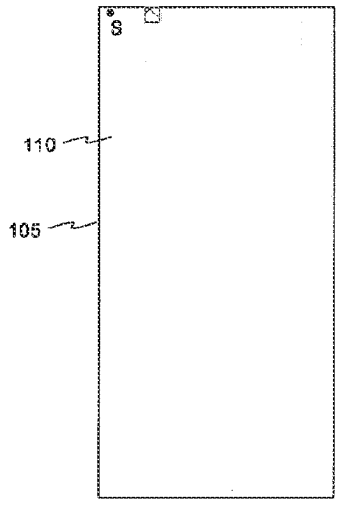


Fig. 2a

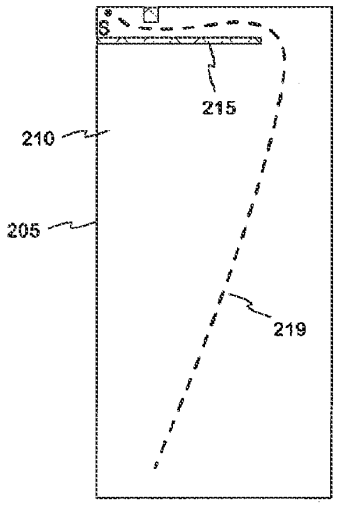
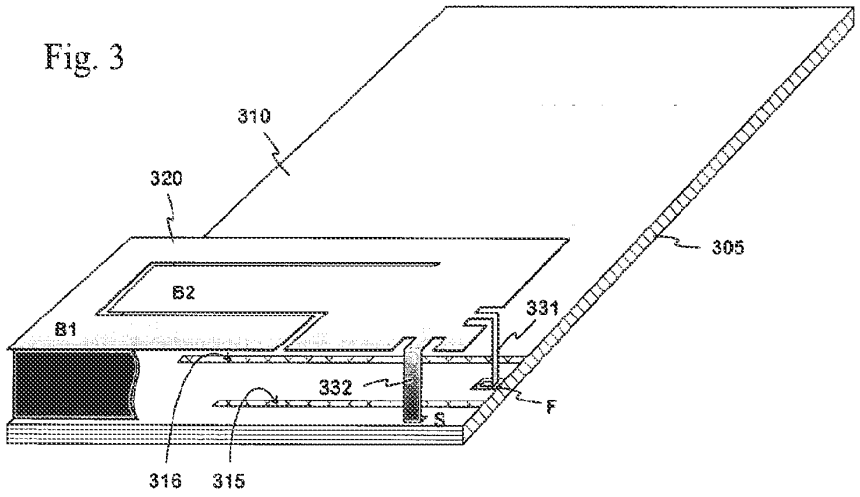


Fig. 2b

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Fig. 3



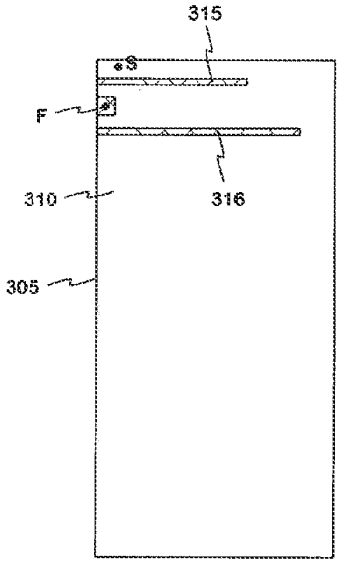


Fig. 4

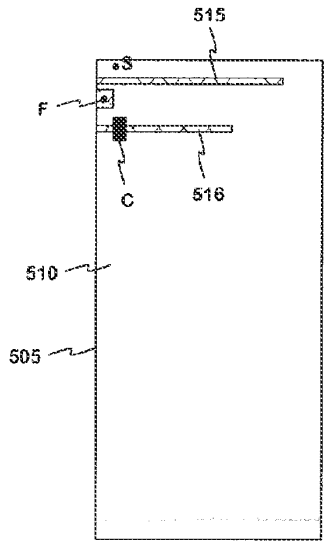


Fig. 5

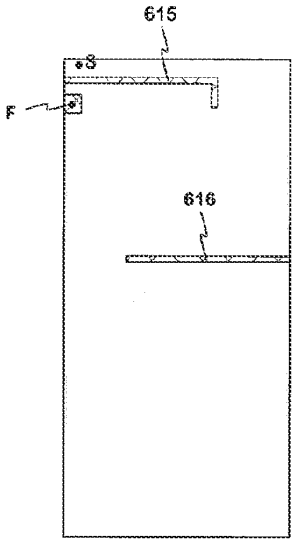


Fig. 6

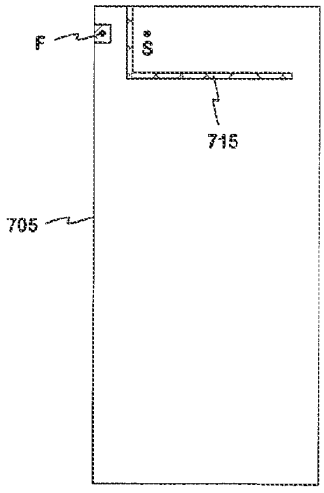


Fig. 7

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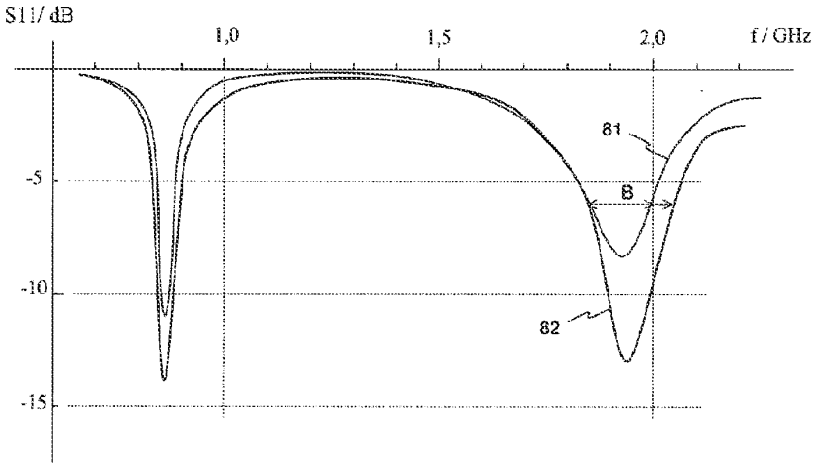


Fig. 8

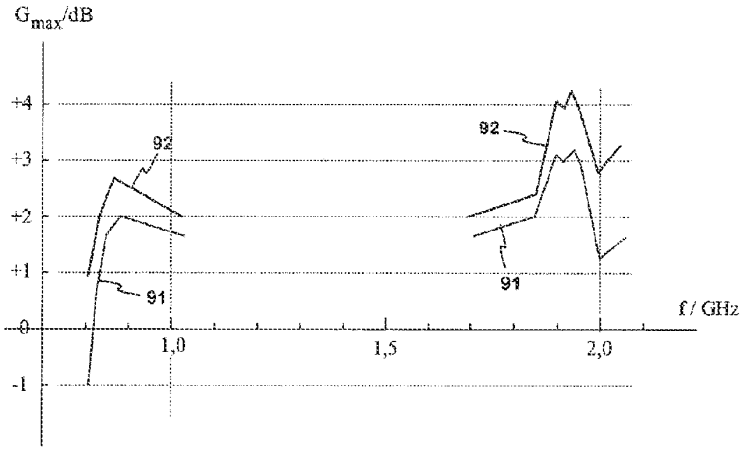


Fig. 9

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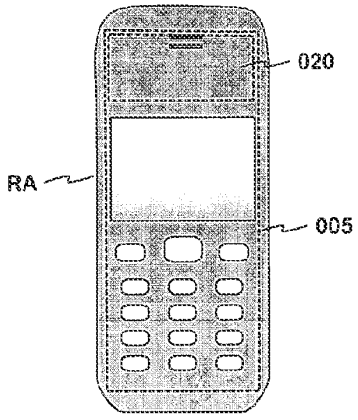


Fig. 10

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 39 6086

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	WO 01 89031 A (AVANTEGO AB ;BJOERKMAN TONY (SE); SJOEHOLM JAN (SE)) 22 November 2001 (2001-11-22) * page 5, line 22-32; figure 1 * ---	1-4,8-12	H01Q9/04 H01Q1/24 H01Q5/00 H01Q1/48
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X	US 5 262 792 A (EGASHIRA YOSHIMI) 16 November 1993 (1993-11-16) * figure 1A * -----	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

H01Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	11 December 2003	Ribbe, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 03 39 6086

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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US 5262792 A	16-11-1993	NONE	

EPO FORM P0459

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

Resmed Corp. - Ex. 1002
Page 577

Electronic Acknowledgement Receipt

EFS ID:	11947815
Application Number:	13341051
International Application Number:	
Confirmation Number:	9540
Title of Invention:	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
First Named Inventor/Applicant Name:	Josep Mumbru
Customer Number:	61060
Filer:	Ross Robinson/Brenda Brown
Filer Authorized By:	Ross Robinson
Attorney Docket Number:	47005-P040WUSC1
Receipt Date:	30-JAN-2012
Filing Date:	30-DEC-2011
Time Stamp:	11:21:03
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	IDS47005P040WUSC1.pdf	199827 1e2444d02330d77f2b6326040ad0427c5661e4a4	no	2

Warnings:	
Information:	

2	Non Patent Literature	NPL17.pdf	14891535 728a7ad50f95dc460220aa7d3d3c248fae1a327a	no	18
Warnings:					
Information:					
3	Non Patent Literature	NPL16.pdf	3946226 85f7e9c15d4d2d0a16ff2900cd7a98623ab8753d	no	5
Warnings:					
Information:					
4	Non Patent Literature	NPL15.pdf	21148777 4be99076bd73a31fe7affd606830cfed5c08af07	no	24
Warnings:					
Information:					
5	Non Patent Literature	NPL14.pdf	15626605 8229ca305086bf0b76398bf697ace6c2c760a7d0	no	18
Warnings:					
Information:					
6	Non Patent Literature	NPL13.pdf	9864548 ab6154cab2058dd4e84611e706995b28ddd16e4e	no	8
Warnings:					
Information:					
7	Non Patent Literature	NPL12.pdf	12584367 45bbeb511662a4fa65528ada9668f3e7cbdc694f	no	11
Warnings:					
Information:					
8	Non Patent Literature	NPL11.pdf	7331225 8667bd799dcc7fc25b3842ffdda7606757088a99	no	8
Warnings:					
Information:					
9	Non Patent Literature	NPL10.pdf	9255048 81af6cfcdec45143a9fe7eb891b77885655909b1	no	9
Warnings:					
Information:					
10	Non Patent Literature	NPL09PART2.pdf	23014089 fe6942522224118680998b7b2a1294f73e5adb07	no	87
Warnings:					
Information:					

11	Non Patent Literature	NPL09PART1.pdf	20024795 dfedcd878c5a466feed298238517c223a0ff3525	no	80
Warnings:					
Information:					
12	Non Patent Literature	NPL08PART2.pdf	23364341 1f51eb404b3c3f2be195aaa5e628e2491713672d	no	97
Warnings:					
Information:					
13	Non Patent Literature	NPL08PART1.pdf	18936043 d5f30f5c46b29d0b2ff62faa60d2632f399f880f	no	80
Warnings:					
Information:					
14	Non Patent Literature	NPL07PART3.pdf	8982061 d584bf4cb9740099a34c4e7fb7494a658b67ecdb	no	40
Warnings:					
Information:					
15	Non Patent Literature	NPL07PART2.pdf	11192447 9e7e615c24fa119e35aae0721f8db2901232e552	no	50
Warnings:					
Information:					
16	Non Patent Literature	NPL07PART1.pdf	12895458 bbf989fbbda07548425468d11c924f1f81ee5cd6	no	50
Warnings:					
Information:					
17	Non Patent Literature	NPL06.pdf	19485293 33fef10e16de41b225b06b9bc3ab9d7d5be0ef73	no	10
Warnings:					
Information:					
18	Non Patent Literature	NPL05.pdf	4722212 cddfb9a18e4188d11b842adddefbb83600b72da0	no	4
Warnings:					
Information:					
19	Non Patent Literature	NPL04.pdf	21568669 036df6a7e9c84630fc57af9b5661a3a1e5e7c7ab	no	10
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Information:					

20	Non Patent Literature	NPL03.pdf	9889443 225186e3c35160599cb641f9dfcfa077e7d37874	no	6
Warnings:					
Information:					
21	Non Patent Literature	NPL02PART2.pdf	16655260 29c6465c139104cc88a7e297ce9611388c38bc35	no	60
Warnings:					
Information:					
22	Non Patent Literature	NPL02PART1.pdf	15251503 b92700d179feff97100173b07babe3b746045de3	no	60
Warnings:					
Information:					
23	Non Patent Literature	NPL01PART2.pdf	15989948 1f5516f4d245fb498ecbdabff636849a72ba3812	no	55
Warnings:					
Information:					
24	Non Patent Literature	NPL01PART1.pdf	13767498 756f53d87adf7bb010918934d1de5c38381bd1e1	no	40
Warnings:					
Information:					
25	Information Disclosure Statement (IDS) Form (SB08)	IDSStatementbyApplicant4700 5P040WUSC1.pdf	573884 38041231580423cc0d218a9e1ca64d1dfcc13e3d	no	5
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
26	Foreign Reference	FPP11PART2.pdf	12215385 bb74f7cb829c2a54700bf365dc449466ca4456ab	no	53
Warnings:					
Information:					
27	Foreign Reference	FPP11PART1.pdf	15975864 72fced7bee8f91a72d67004ee36abd7e3f15e0a2	no	50
Warnings:					
Information:					
28	Foreign Reference	FPP10.pdf	20118511 8118ae4e58e81e78c3f5133f14117ee9348e1210	no	23

Warnings:					
Information:					
29	Foreign Reference	FPP09PART2.pdf	10343913 d160e496c888f4c9cb55a3dca4b0a2dca7b759b2	no	13
Warnings:					
Information:					
30	Foreign Reference	FPP09PART1.pdf	21081744 9e8065f3ed468736d603c10a122695a330fc4065	no	20
Warnings:					
Information:					
31	Foreign Reference	FPP08.pdf	18371173 b467ae330784ed4923296a6a47e1084b91ce3442	no	20
Warnings:					
Information:					
32	Foreign Reference	FPP07.pdf	9275873 76e68d82671c527324c7bed775c272e4fb27fbc8	no	31
Warnings:					
Information:					
33	Foreign Reference	FPP06.pdf	2507729 2e1a8eefc21e2d852c948ad4dfc9badec22a30e5	no	20
Warnings:					
Information:					
34	Foreign Reference	FPP05.pdf	7998413 3d461e8f05521ceda141fde94273109484233f9e	no	40
Warnings:					
Information:					
35	Foreign Reference	FPP04.pdf	10955766 b72d091e75bb6e6c2dce24d672acec537eab6c04	no	53
Warnings:					
Information:					
36	Foreign Reference	FPP03PART2.pdf	14082980 9ded4e307035af556c1736ddd82e0bacc4eff7fe	no	10
Warnings:					
Information:					
37	Foreign Reference	FPP03PART1.pdf	11872069 99b5e7ada722a6ffdfde1763771b0768bce9ecb4	no	10

Warnings:					
Information:					
38	Foreign Reference	FPP02PART2.pdf	2585335 82de3b75c052978d92cac8a79881e1ef3d3dc52d	no	39
Warnings:					
Information:					
39	Foreign Reference	FPP02PART1.pdf	7756991 5a4fad05310a57913bc4a1114db225cfd3b27a25	no	35
Warnings:					
Information:					
40	Foreign Reference	FPP01.pdf	10244885 c28bab173848f5adcc7c325b20649f57de45c98a	no	12
Warnings:					
Information:					
			Total Files Size (in bytes):	506547733	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being transmitted via the Office electronic filing system in accordance with § 1.6(a)(4).

Dated: January 30, 2012
Electronic Signature for Brenda I. Brown: /Brenda I. Brown/

Docket No.: 47005-P040WUSC1
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Josep Mumbru et al.

Application No.: 13/341,051

Confirmation No.: 9540

Filed: December 30, 2011

Art Unit: 2821

For: HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS

Examiner: Not Yet Assigned

INFORMATION DISCLOSURE STATEMENT (IDS)

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Pursuant to 37 CFR 1.56, 1.97 and 1.98, the attention of the Patent and Trademark Office is hereby directed to the references listed on the attached PTO/SB/08. It is respectfully requested that the information be expressly considered during the prosecution of this application, and that the references be made of record therein and appear among the "References Cited" on any patent to issue therefrom.

This Information Disclosure Statement is filed within three months of the U.S. filing date (37 CFR 1.97(b)(1)).

A summary/abstract translation of the non-English language references as indicated is enclosed.

Applicant has not submitted copies of each cited U.S. patent and U.S. patent application in accordance with 37 CFR 1.98(a)(2). Applicant submits herewith copies of any cited non-patent documents and foreign patent documents in accordance with 37 CFR 1.98(a)(2).

In accordance with 37 CFR 1.97(g), the filing of this Information Disclosure Statement shall not be construed to mean that a search has been made or that no other material information as defined in 37 CFR 1.56(a) exists. In accordance with 37 CFR 1.97(h), the filing of this Information Disclosure Statement shall not be construed to be an admission that any patent, publication or other information referred to therein is "prior art" for this invention unless specifically designated as such.

It is submitted that the Information Disclosure Statement is in compliance with 37 CFR 1.98 and the Examiner is respectfully requested to consider the listed references.

The Director is hereby authorized to charge any deficiency in the fees filed, asserted to be filed or which should have been filed herewith (or with any paper hereafter filed in this application by this firm) to our Deposit Account No. 23-2426, under Order No. 47005-P040WUSC1.

Dated: January 30, 2012

Respectfully submitted,

Electronic signature: /Shoaib A. Mithani/
Shoaib A. Mithani
Registration No.: 61,654
WINSTEAD PC
P.O. Box 50784
Dallas, Texas 75201
(214) 745-5400
Attorneys For Applicant

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:

see form PCT/ISA/220

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP2006/007050	18.07.2006	21.07.2005

International Patent Classification (IPC) or both national classification and IPC
INV. H01Q1/38 H01Q5/00 H01Q13/10 H01Q1/24 H01Q21/28

Applicant
FRACTUS, S.A.

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☒ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notifed the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA:	Date of completion of this opinion	Authorized Officer
European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	See form PCT/ISA/210	Wattiaux, Véronique Telephone No. +31 70 340-4463

Form (PCT/ISA/237) (Cover Sheet) (April 2005)

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

      ☐ a sequence listing

      ☐ table(s) related to the sequence listing

   b. format of material:

      ☐ on paper

      ☐ in electronic form

   c. time of filing/furnishing:

      ☐ contained in the international application as filed.

      ☐ filed together with the international application in electronic form.

      ☐ furnished subsequently to this Authority for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. IV Lack of unity of invention

1. ☐ In response to the invitation (Form PCT/ISA/206) to pay additional fees, the applicant has, within the applicable time limit:

   ☐ paid additional fees

   ☐ paid additional fees under protest and, where applicable, the protest fee

   ☐ paid additional fees under protest but the applicable protest fee was not paid

   ☐ not paid additional fees

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose not to invite the applicant to pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rule 13.1, 13.2 and 13.3 is

   ☐ complied with

   ☒ not complied with for the following reasons:

   see separate sheet

4. Consequently, this report has been established in respect of the following parts of the international application:

   ☐ all parts.

   ☒ the parts relating to claims Nos. 1,2,8-20,32-34,42,43,46-50,53,73

Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	
	No:	Claims	1,2,8-20,32-34,42,43,46-50,53,73
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1,2,8-20,32-34,42,43,46-50,53,73
Industrial applicability (IA)	Yes:	Claims	1,2,8-20,32-34,42,43,46-50,53,73
	No:	Claims	

2. Citations and explanations

   see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item IV

This Authority considers that there are 9 inventions covered by the claims indicated as follows:

I: Claims 1,2,8 to 20,32 to 34,42,43,46 to 50,53 and 73 directed to a multiband handheld device.
II: Claims 3 to 7 directed to an antenna to be embodied in the conductive layer of a surface mount technology component.
III: Claims 21 to 31, 59 to 62, 64 to 67,70 directed to the use of a slot in a ground plane to provide isolation between two antennas.
IV: Claims 35 to 41 directed to space filling curve antennas.
V: Claims 44,45 directed to slidable ground planes.
VI: Claims 54 to 58 directed to a method to modify the radiation portion of an antenna.
VII: Claim 63 directed to the use of a conductive strip connected to ground.
VIII: Claim 68 directed to the use of a strip placed between two antennas to shield these antennas.
IX: Claims 51,52,71,72 and 74 directed to polarization diversity.

The reasons for which the inventions are not so linked as to form a single general inventive concept, as required by Rule 13.1 PCT, are as follows:

Examining the possible correspondence by technical effect, one finds that the technical effect of the first invention is how to achieve multiband; the technical effect of the second invention is how to implement an antenna on a SMT component; that of the third invention is how to provide isolation between two antennas, that of the fourth invention is to save antenna space by using space filling curve antennas, that of the fifth invention is to miniaturize the size of a handheld device by using slidable portions, that of the sixth invention is how to modify the length of the shape of a radiating element; that of the seventh invention is directed to the use of a conductive strip connected to ground to use it for eg. as a parasitic element; that of the eight invention is how to shield two antennas and the last invention is directed to polarization diversity.

This appears to show lack of corresponding technical effect as well. Consequently, neither the objective problem underlying the subjects of the claimed inventions, nor their solutions defined by the special technical features allow for a relationship to be

established between the said inventions, which involves a single general inventive concept.
In conclusion, the groups of claims are not linked by common or corresponding special technical features and define 9 different inventions not linked by a single general inventive concept.
The application, hence does not meet the requirements of unity of invention as defined in Rules 13.1 and 13.2 PCT.

Re Item V
Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents :

   D1: US-B1-6 337 662 (CASSEL ERLAND) 8 January 2002 (2002-01-08)
   D2: WO 2004/102744 A (KONINKLIJKE PHILIPS ELECTRONICS N.V; BOYLE, KEVIN, R) 25 November 2004 (2004-11-25)

2. The present application does not meet the criteria of Article 33(1) PCT, because the subject-matter of independent claims 1 and 53 is not new in the sense of Article 33(2) PCT.

   2.1 Analysis of claim 1 :
   The document D1 discloses in column 1, lines 5 to 10 and lines 28 to 30 :
   A handheld device comprising:
   - at least one printed circuit board
   - a first antenna arranged to operate in at least a first frequency band,
   - a second antenna arranged to operate in at least a second frequency band,[0050]

   wherein the said second frequency band is different from said first frequency band;
   and wherein the said second antenna comprises a slot antenna comprising at least one slot in at least one conductive layer.
   Therefore, claim 1 is not novel.

   2.2 Analysis of claim 53 :

The document D2 discloses (the references in parentheses applying to this document):

A handheld device comprising: (fig.2)

- a first antenna operating in at least a first frequency band, (fig.2,16)
- a second antenna operating in at least a second frequency band, (fig.2,14)
- a printed circuit board including a ground plane, (fig.2,12)

wherein the said second frequency band is different from the said first frequency band; (page 2, lines 3 to 10)

wherein the said first antenna is selected from the group consisting essentially of monopole antenna, IFA, patch antenna, and PIFA; (page 2, line 9)

wherein the said second antenna comprises a slot antenna , wherein the said slot antenna is included in the ground plane of the said printed circuit board, (page 2, lines 8 to 10).

wherein the longest straight segment of the slot is substantially parallel to the longest edge of the said printed circuit board, (fig.7)

wherein one open end of the slot is in contact with one edge of the said printed circuit board; (fig.2, 20)

wherein the width of the rectangular area in which the said slot antenna is inscribed, divided by a free-space operating wavelength of the said slot antenna is smaller than, or equal to, at least one of the following fractions: 1/10,1/30, 1/50, 1/60, 1/70, or 1/80;(fig.7)

wherein the length of the rectangular area in which the said slot antenna is inscribed, divided by a free-space operating wavelength of the said slot antenna is smaller than, or equal to, at least one of the following fractions: ½, 1/3, or 1/4; (fig.7)

wherein the said handheld device is a mobile handset, operating in at least one of the following mobile communication and wireless connectivity services: GSM (GSM85O, GSM900, GSMI800, American GSM or PCSI900, GSM45O), UMTS, WCDMA, CDMA, BluetoothTM, IEEE8O2.llba, IEEE8O2.llb, IEEE8O2.llg, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARS, XDARS, WiMAX, DAB, FM, DMB. (page 4, lines 10 to 20)

Therefore, claim 53 is not novel.

3. Dependent claims 2,8 to 20,32 to 34,42,43,46 to 50,53 and 73 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step because :
The additional technical features of claims 2,8,9,11,12,13,14,15,16,18,20,32,42,43,46,47,48,49,50 and 73 are further disclosed in D1, these claims are therefore not novel.
The additional technical features present in claims 10,17,19,33 and 34 are consequences of a particular choice (in the design of an antenna), these having no surprising effect.

Re Item VIII

The application does not meet the requirements of Article 6 PCT, because claims 14,15 and 73 are not clear.

1. What is the unfolded length of a slot antenna ? This means that the slot has a certain geometry. However, this geometry is neither defined in claims 14,15 nor is it defined in the claims to which they depend on.

2. Claim 73 is not clear : there are two reasons as to why an antenna is used : to transmit or to receive electromagnetic waves. If the process of connecting wirelessly using an antenna is claimed, then all the essential technical features are missing in the claims.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

To:
HERRERO & ASOCIADOS, S.L.
Attn. Carpintero Lopez, F.
Alcalá 35
E-28014 Madrid
ESPAGNE

Date of mailing *(day/month/year)* 13/12/2006	
Applicant's or agent's file reference 20060523	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/EP2006/007050	International filing date *(day/month/year)* 18/07/2006

Applicant
FRACTUS, S.A.

1. [x] The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the International Search Report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Fascimile No.: (41-22) 338.82.70

   For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Mustafa Corapci

Form PCT/ISA/220 (October 2005) *(See notes on accompanying sheet)*

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the *PCT Applicant's Guide*, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report and the written opinion of the International Searching Authority, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims,description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only (see *PCT Applicant's Guide*, Volume I/A, Annexes B1 and B2).

The attention of the apolicant is drawn to the fact that amendments to the claims under Article 19 are not allowed where the International Searching Authority has declared, under Article 17(2), that no international search report would be established (see *PCT Applicant's Guide*, Volume I/A, paragraph 296).

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 46 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments and any accompanying statement, under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the time of filing the amendments (and any statement) with the International Bureau, also file with the International Preliminary Examining Authority a copy of such amendments (and of any statement) and, where required, a translation of such amendments for the procedure before that Authority (see Rules 55.3(a) and 62.2, first sentence). For further information, see the Notes to the demand form (PCT/IPEA/401).

If a demand for international preliminary examination is made, the written opinion of the International Searching Authority will, except in certain cases where the International Preliminary Examining Authority did not act as International Searching Authority and where it has notified the International Bureau under Rule 66.1*bis*(b), be considered to be a written opinion of the International Preliminary Examining Authority. If a demand is made, the applicant may submit to the International Preliminary Examining Authority a reply to the written opinion together, where appropriate, with amendments before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later (Rule 43*bis*.1(c)).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see the *PCT Applicant's Guide*, Volume II.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
20060523		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/EP2006/007050	18/07/2006	21/07/2005
Applicant		
FRACTUS, S.A.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 6 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      ☒ the international application in the language in which it was filed
      ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (See Box No. II)

3. ☒ **Unity of invention is lacking** (see Box No III)

4. With regard to the **title**,
   ☒ the text is approved as submitted by the applicant
   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   ☒ the text is approved as submitted by the applicant
   ☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings**,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 4
      ☒ as suggested by the applicant
      ☐ as selected by this Authority, because the applicant failed to suggest a figure
      ☐ as selected by this Authority, because this figure better characterizes the invention
   b. ☐ none of the figures is to be published with the abstract

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2006/007050

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1,2,8-20,32-34,42,43,46-50,53,73

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1,2,8-20,32-34,42,43,46-50,53,73

   multiband handheld device.

   ---

2. claim: 3 to 7

   antenna embodied in a conductive layer of a surface mount technology component.

   ---

3. claims: 21-31,59-62,64-67,70

   isolation means between two antennas.

   ---

4. claim: 35 to 41

   space filling curve antennas.

   ---

5. claims: 44,45

   slidable ground planes.

   ---

6. claim: 54 to 58

   method to modify the radiation portion of an antenna.

   ---

7. claim: 63

   use of a conductive strip connected to ground.

   ---

8. claim: 68

   use of a strip placed between two antennas to shield these antennas.

   ---

9. claims: 51,52,71,72,74

   polarization diversity.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2006/007050

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01Q1/38 H01Q5/00 H01Q13/10 H01Q1/24 H01Q21/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 337 662 B1 (CASSEL ERLAND) 8 January 2002 (2002-01-08) the whole document	1,2, 8-20, 32-34, 42,43, 46-50, 53,73
X	WO 2004/102744 A (KONINKLIJKE PHILIPS ELECTRONICS N.V; BOYLE, KEVIN, R) 25 November 2004 (2004-11-25) the whole document	1,2, 8-20, 32-34, 42,43, 46-50, 53,73

-/--

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 September 2006	13. 12. 2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Wattiaux, Véronique

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

Resmed Corp. - Ex. 1002
Page 600

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2006/007050

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 445 821 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD) 11 August 2004 (2004-08-11) the whole document	1,2, 8-20, 32-34, 42,43, 46-50, 53,73
X	US 2002/175879 A1 (SABET KAZEM F ET AL) 28 November 2002 (2002-11-28) the whole document	1,2, 8-20, 32-34, 42,43, 46-50, 53,73
X	EP 1 401 050 A (FILTRONIC LK OY) 24 March 2004 (2004-03-24) the whole document	1,2, 8-20, 32-34, 42,43, 46-50, 53,73
A	US 2002/167450 A1 (KORDEN CHRISTIAN ET AL) 14 November 2002 (2002-11-14) the whole document	1

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

Resmed Corp. - Ex. 1002
Page 601

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2006/007050

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6337662 B1	08-01-2002	BR 9809332 A	04-07-2000
		BR 9809782 A	20-06-2000
		DE 19882352 T0	25-05-2000
		DE 19882353 T0	13-04-2000
		EP 0979536 A1	16-02-2000
		EP 1016159 A1	05-07-2000
		JP 2001523414 T	20-11-2001
		JP 2001522558 T	13-11-2001
		SE 511295 C2	06-09-1999
		SE 9701646 A	04-02-1999
		WO 9849742 A1	05-11-1998
		WO 9849743 A1	05-11-1998
		US 2002030627 A1	14-03-2002
WO 2004102744 A	25-11-2004	EP 1625639 A1	15-02-2006
		KR 20060013399 A	09-02-2006
EP 1445821 A	11-08-2004	CN 1520130 A	11-08-2004
		CN 1520131 A	11-08-2004
		EP 1445824 A1	11-08-2004
		KR 20040071655 A	12-08-2004
		KR 20040071656 A	12-08-2004
		US 2006109185 A1	25-05-2006
		US 2004227673 A1	18-11-2004
		US 2004219956 A1	04-11-2004
US 2002175879 A1	28-11-2002	US 2002000944 A1	03-01-2002
EP 1401050 A	24-03-2004	CN 1495966 A	12-05-2004
		FI 20021668 A	20-03-2004
		US 2004058723 A1	25-03-2004
US 2002167450 A1	14-11-2002	WO 0137215 A1	25-05-2001
		EP 1232477 A1	21-08-2002

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/341,051	12/30/2011	Josep Mumbru	47005-P040WUSC1	9540

61060 7590 02/22/2012

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

EXAMINER	
NGUYEN, HOANG V	
ART UNIT	PAPER NUMBER
2821	

MAIL DATE	DELIVERY MODE
02/22/2012	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	13/341,051	MUMBRU ET AL.	
	Examiner	Art Unit	
	HOANG V. NGUYEN	2821	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *30 December 2011*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

5)☒ Claim(s) *1-20* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1-20* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *30 December 2011* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

12)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

13)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☒ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

Double Patenting

A rejection based on double patenting of the "same invention" type finds its support in the language of 35 U.S.C. 101 which states that "whoever invents or discovers any new and useful process ... may obtain a patent therefor ..." (Emphasis added). Thus, the term "same invention," in this context, means an invention drawn to identical subject matter. See *Miller v. Eagle Mfg. Co.*, 151 U.S. 186 (1894); *In re Ockert*, 245 F.2d 467, 114 USPQ 330 (CCPA 1957); and *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970).

A statutory type (35 U.S.C. 101) double patenting rejection can be overcome by canceling or amending the conflicting claims so they are no longer coextensive in scope. The filing of a terminal disclaimer cannot overcome a double patenting rejection based upon 35 U.S.C. 101.

Claims 1-20 are rejected under 35 U.S.C. 101 as claiming the same invention as that of claims 1-18, 38 and 39 of prior U.S. Patent No. 8,115,686. This is a double patenting rejection.

Inquiry

Any inquiry concerning this communication or earlier communications from the examiner should be directed to HOANG V. NGUYEN whose telephone number is (571)272-1825. The examiner can normally be reached on Mondays-Fridays from 9:00 a.m. to 5:00 p.m..

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jacob Y. Choi can be reached on (571) 272-2367. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR

system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/HOANG V NGUYEN/
Primary Examiner, Art Unit 2821

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13341051	MUMBRU ET AL.
	Examiner	Art Unit
	HOANG V NGUYEN	2821

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	02/17/2012								
	1	✓								
	2	✓								
	3	✓								
	4	✓								
	5	✓								
	6	✓								
	7	✓								
	8	✓								
	9	✓								
	10	✓								
	11	✓								
	12	✓								
	13	✓								
	14	✓								
	15	✓								
	16	✓								
	17	✓								
	18	✓								
	19	✓								
	20	✓								

UNITED STATES PATENT AND TRADEMARK OFFICE

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United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/341,051	12/30/2011	Josep Mumbru	47005-P040WUSC1

CONFIRMATION NO. 9540

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

PUBLICATION NOTICE

OC000000053942874

Title:HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS

Publication No.US-2012-0098719-A1
Publication Date:04/26/2012

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being transmitted via the Office electronic filing system in accordance with § 1.6(a)(4).

Dated: May 14, 2012
Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

Docket No. 47005-P040WUSC1
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Josep Mumbru et al.

Application No. 13/341,051 | Confirmation No. 9540

Filed: December 30, 2011 | Art Unit: 2821

For: HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS | Examiner: H. V. Nguyen

AMENDMENT IN RESPONSE TO NON-FINAL OFFICE ACTION

MS Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

INTRODUCTORY COMMENTS

In response to the Office Action dated February 22, 2012, please amend the above-identified U.S. patent application as follows:

Amendments to the Claims are reflected in the listing of claims which begins on page 2 of this paper.

Remarks/Arguments begin on page 7 of this paper.

AMENDMENTS TO THE CLAIMS

1-20. (Canceled)

21. (New) A handheld device comprising:

a substantially rectangular ground plane;

a first antenna capable of transmitting and receiving electromagnetic wave signals in at least three frequency bands used for mobile communication services;

a second antenna capable of operating in at least one frequency band;

wherein the first antenna extends in a direction substantially parallel to a first side of the substantially rectangular ground plane;

wherein the second antenna extends in a direction substantially parallel to a second side of the substantially rectangular ground plane; and

wherein the first antenna is arranged near a short side of the substantially rectangular ground plane.

22. (New) The handheld device according to claim 21, wherein said handheld device further comprises at least one slot in the substantially rectangular ground plane, wherein said at least one slot is arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said substantially rectangular ground plane between said feeding points in at least one frequency band corresponding to an operating band of one of said first and second antennas.

23. (New) The handheld device according to claim 22, wherein said at least one slot in the substantially rectangular ground plane has an open end in correspondence with a perimeter of said substantially rectangular ground plane.

24. (New) The handheld device according to claim 22, wherein said at least one slot has a length of approximately (2N-1)*A/4, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, N>1.

25. (New) The handheld device according to claim 21, further comprising at least one conductive strip connected to the substantially rectangular ground plane, wherein said at least one conductive strip is arranged so as to provide a high impedance path in said substantially rectangular ground plane between a feeding point of said first antenna and a feeding point of said second antenna in at least one frequency band corresponding to an operating band of one of said first and second antennas.

26. (New) The handheld device according to claim 25, wherein said at least one conductive strip has a length from its connection to the substantially rectangular ground plane, of approximately (2N-1)*A/4, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, N>1.

27. (New) The handheld device according to claim 21, wherein the second antenna is arranged to operate in at least one frequency band used for a wireless service in accordance with Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB.

28. (New) The handheld device according to claim 21, wherein said handheld device further comprises two or more slots in the substantially rectangular ground plane arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said substantially rectangular ground plane between said feeding points in at least one frequency band corresponding to an operating band of one of said first and second antennas.

29. (New) The handheld device according to claim 21, wherein the first side and the second side are substantially orthogonal.

30. (New) The handheld device according to claim 21, wherein the first side and the second side are substantially parallel.

31. (New) A handheld device comprising:

a printed circuit board including a substantially rectangular ground plane;

a first antenna operating in a plurality of frequency bands, said first antenna being capable of transmitting and receiving electromagnetic wave signals in each frequency band of said plurality of frequency bands;

a second antenna operating in at least a first frequency band, said second antenna being capable of transmitting and receiving electromagnetic wave signals in said first frequency band;

wherein the first antenna is arranged substantially close to a short side of the substantially rectangular ground plane;

wherein the second antenna is a slot antenna comprising a slot;

wherein the first antenna extends in a direction substantially parallel to said short side of the substantially rectangular ground plane;

wherein a width of a rectangular area in which the slot antenna is inscribed, divided by a free-space operating wavelength of the slot antenna is smaller than, or equal to, at least one of the following fractions: 1/10, 1/30, 1/50, 1/60, 1/70, or 1/80;

wherein a length of the rectangular area in which the slot antenna is inscribed, divided by a free-space operating wavelength of the slot antenna is smaller than, or equal to, at least one of the following fractions: 1/2, 1/3, or 1/4; and

wherein the first antenna operates in at least three frequency bands used for mobile communication services.

32. (New) The handheld device according to claim 31, wherein the slot antenna is not on a projection area of the first antenna.

33. (New) The handheld device according to claim 31, wherein the slot antenna extends in a direction substantially parallel to a long side of the substantially rectangular ground plane.

34. (New) The handheld device according to claim 31, wherein the second antenna is arranged to operate in at least one frequency band used for a wireless service in accordance with Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB.

35. (New) A handheld device comprising:

a printed circuit board including a substantially rectangular ground plane;

a first antenna operating in a plurality of frequency bands, said first antenna being capable of transmitting and receiving electromagnetic wave signals in each frequency band of said plurality of frequency bands;

a second antenna operating in at least one frequency band;

wherein the second antenna comprises a slot;

wherein the first antenna extends in a direction substantially parallel to a first side of the substantially rectangular ground plane;

wherein the second antenna extends in a direction substantially parallel to a second side of the substantially rectangular ground plane;

wherein the second antenna is not on a projection area of the first antenna.

36. (New) The handheld device of claim 35, wherein the first antenna comprises a non-conducting material provided under at least 50% of a projection area of the first antenna.

37. (New) The handheld device of claim 35, wherein the at least one frequency band is different from any frequency band of the plurality of frequency bands.

38. (New) The handheld device of claim 35, wherein the first side and the second side are substantially orthogonal.

39. (New) The handheld device of claim 35, wherein the second antenna is printed as a conductive layer on the printed circuit board or is etched from a conductive layer of the printed circuit board.

40. (New) The handheld device according to claim 35, wherein the second antenna is embedded in an SMT component.

REMARKS

Claims 21-40 are currently pending in the application. New claims 21-40 have been added. Claims 1-20 have been canceled. Applicant respectfully submits that no new matter has been added. Applicant respectfully requests reconsideration of the application in view of the foregoing amendments and the following remarks.

Claims 1-20 stand rejected on the grounds of 35 U.S.C. 101 double patenting as claiming the same invention as that of claims 1-18 and 38-39 of U.S. Patent No. 8,115,686. Claims 1-20 have been canceled, thus rendering the 35 U.S.C. 101 double patenting rejection thereof moot.

In view of the above, Applicant respectfully submits that the present application is in condition for allowance. A Notice to that effect is respectfully requested.

Dated: May 14, 2012

Respectfully submitted,

Electronic signature: /Shoaib A. Mithani/
Shoaib A. Mithani
Registration No.: 61,654
WINSTEAD PC
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(214) 745-5400
Attorneys For Applicant

Electronic Acknowledgement Receipt

EFS ID:	12765021
Application Number:	13341051
International Application Number:	
Confirmation Number:	9540
Title of Invention:	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
First Named Inventor/Applicant Name:	Josep Mumbru
Customer Number:	61060
Filer:	Shoaib Amirali Mithani
Filer Authorized By:	
Attorney Docket Number:	47005-P040WUSC1
Receipt Date:	14-MAY-2012
Filing Date:	30-DEC-2011
Time Stamp:	09:42:42
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Amendment/Req. Reconsideration-After Non-Final Reject	47005Response.pdf	32787 b8e062924f7d04abbac37167444b44890093dac5	no	7

Warnings:	
Information:	

Total Files Size (in bytes):	32787

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number	Filing Date	☐ To be Mailed
13/341,051	12/30/2011	

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)	SMALL ENTITY ☐		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT 05/14/2012	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 20	Minus	** 20	=	X $ =		OR	X $ =	
Independent (37 CFR 1.16(h))	* 3	Minus	***3	=	X $ =		OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

AMENDMENT	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)	OR	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))									
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/TERRANCE LAWRENCE/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/341,051	12/30/2011	Josep Mumbru	47005-P040WUSC1	9540

61060 7590 06/21/2012

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

EXAMINER	
NGUYEN, HOANG V	
ART UNIT	PAPER NUMBER
2821	

MAIL DATE	DELIVERY MODE
06/21/2012	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	13/341,051	MUMBRU ET AL.	
	Examiner	Art Unit	
	HOANG V. NGUYEN	2821	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *14 May 2012*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

5)☒ Claim(s) *21-40* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☒ Claim(s) *31-40* is/are allowed.

7)☒ Claim(s) *21,27 and 30* is/are rejected.

8)☒ Claim(s) *22-26,28 and 29* is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *30 December 2011* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

12)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

13)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☒ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date *1/30/12*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

2. Claims 21, 27 and 30 are rejected under 35 U.S.C. 102(b) as being anticipated by Inatsugu et al (US 7,193,571 B2).

Regarding claim 21, Inatsugu (Figure 1) discloses a handheld device comprising a substantially rectangular ground plane 12; a first antenna 16 (upper) capable of transmitting and receiving electromagnetic wave signals in at least three frequency bands used for mobile communication services (col 2, lines 19-21); a second antenna 16 (lower) capable of operating in at least one frequency band; wherein the first antenna extends in a direction substantially parallel to a first side (upper side) of the substantially rectangular ground plane; wherein the second antenna extends in a direction substantially parallel to a second side (lower side) of the substantially rectangular ground plane; and wherein the first antenna is arranged near a short side of the substantially rectangular ground plane.

Regarding claim 27, as applied to claim 21, Inatsugu (col 6, lines 14-17) teaches that the second antenna is arranged to operate in at least one frequency band used for a wireless service in accordance with Bluetooth ^{TM,} IEEES02.1 la, IEEES02.1 lb, IEEES02.1 lg, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB.

Regarding claim 30, as applied to claim 21, Figure 1 of Inatsugu shows that the first ide and the second side are substantially parallel.

Allowable Subject Matter

3. Claims 22-26, 28 are 29 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

4. Claims 31-40 are allowed.

5. The following is a statement of reasons for the indication of allowable subject matter:

Regarding claim 22, Inatsugu discloses the claimed invention except that said handheld device further comprises at least one slot in the substantially rectangular ground plane, wherein said at least one slot is arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said substantially rectangular ground plane between said feeding points in at least one frequency band corresponding to an operating band of one of said first and second antennas.

Claims 23 and 24 would have been found allowable for depending on claim 22.

Regarding claim 25, Inatsugu discloses the claimed invention except further comprising at least one conductive strip connected to the substantially rectangular ground plane, wherein said at least one conductive strip is arranged so as to provide a high impedance path in said substantially rectangular ground plane between a feeding point of said first antenna and a feeding point of said second antenna in at least one frequency band corresponding to an operating band of one of said first and second antennas.

Claim 26 would have been found allowable for depending on claim 25.

Regarding claim 28, Inatsugu discloses the claimed invention except that said handheld device further comprises two or more slots in the substantially rectangular ground plane arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said substantially rectangular ground plane between said feeding points in at least one frequency band corresponding to an operating band of one of said first and second antennas.

Regarding claim 29, Inatsugu discloses the claimed invention except that the first side and the second side are substantially orthogonal.

Regarding claim 31, Inatsugu discloses a handheld device comprising a printed circuit board including a substantially rectangular ground plane; a first antenna operating in a plurality of frequency bands, said first antenna being capable of transmitting and receiving electromagnetic wave signals in each frequency band of said plurality of frequency bands; a second antenna operating in at least a first frequency band, said second antenna being capable of transmitting and receiving electromagnetic wave signals in said first frequency band; wherein the first antenna is arranged substantially close to a short side of the substantially rectangular ground plane; wherein the first antenna extends in a direction substantially parallel to said short side of the substantially rectangular ground plane; and wherein the first antenna operates in at least three frequency bands used for mobile communication services. Inatsugu, however, fails to specifically teach that the second antenna is a slot antenna comprising a slot; wherein a width of a rectangular area in which the slot antenna is inscribed, divided by a free-space operating wavelength of the slot antenna is smaller than, or equal to, at least one of the following fractions: 1/10, 1/30, 1/50, 1/60, 1/70, or 1/80; wherein a length of the rectangular

area in which the slot antenna is inscribed, divided by a free-space operating wavelength of the slot antenna is smaller than, or equal to, at least one of the following fractions: 1/2, 1/3, or ¼.

Claims 32-34 are allowed for depending on claim 31.

Regarding claim 35, Inatsugu discloses a handheld device comprising a printed circuit board including a substantially rectangular ground plane; a first antenna operating in a plurality of frequency bands, said first antenna being capable of transmitting and receiving electromagnetic wave signals in each frequency band of said plurality of frequency bands; a second antenna operating in at least one frequency band; wherein the first antenna extends in a direction substantially parallel to a first side of the substantially rectangular ground plane; wherein the second antenna extends in a direction substantially parallel to a second side of the substantially rectangular ground plane; wherein the second antenna is not on a projection area of the first antenna. Inatsugu, however, fails to specifically teach that the second antenna comprises a slot.

Claims 36-40 are allowed for depending on claim 35.

Conclusion

6. Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after

the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

7. Any inquiry concerning this communication or earlier communications from the examiner should be directed to HOANG V. NGUYEN whose telephone number is (571)272-1825. The examiner can normally be reached on Mondays-Fridays from 9:00 a.m. to 5:00 p.m..

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jacob Y. Choi can be reached on (571) 272-2367. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/HOANG V NGUYEN/
Primary Examiner, Art Unit 2821

Notice of References Cited	Application/Control No. 13/341,051	Applicant(s)/Patent Under Reexamination MUMBRU ET AL.	
	Examiner HOANG V. NGUYEN	Art Unit 2821	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-7,193,571	03-2007	Inatsugu et al.	343/702
	B	US-			
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13341051	MUMBRU ET AL.
	Examiner	Art Unit
	HOANG V NGUYEN	2821

SEARCHED			
Class	Subclass	Date	Examiner
343	702, 700MS, 846, 767	6/1/124	HN

SEARCH NOTES		
Search Notes	Date	Examiner
EAST	6/14/12	HN
Inventor name search	6/1/124	HN

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

Receipt date: 1/30/2012

13341051 - GAU: 2821

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	13341051
Filing Date	2011-12-30
First Named Inventor	Josep Mumbru
Art Unit	2821
Examiner Name	~~Not Yet Assigned~~ Hoang V Nguyen
Attorney Docket Number	47005-P040WUSC1

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	4739289		1988-04-19	Cripps	
	2	5666125		1997-09-09	Luxon	
	3	5784032		1998-07-21	Johnston	
	4	5990838		1999-11-23	Burns et al	
	5	6204819		2001-03-20	Hayes et al	
	6	6337662		2002-01-08	Cassel	
	7	6424300		2002-07-23	Sandford	
	8	6606071		2003-08-12	Cheng et al	

EFS Web 2.1.17

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.N./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13341051 13341051 - GAU: 2821
	Filing Date	2011-12-30
	First Named Inventor	Josep Mumbru
	Art Unit	2821
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	47005-P040WUSC1

	9	6624789		2003-09-23	Kangasvieri et al	
	10	6985108		2006-01-10	Mikkola et al	
	11	7170450		2007-01-30	Chang	

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U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020167450		2002-11-14	Korden et al	
	2	20020175879		2002-11-28	Sabet et al.	
	3	20030193437		2003-10-16	Kangasvieri	
	4	20070279289		2007-12-06	Baliarda et al	

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FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]

EFS Web 2.1.17 ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.N./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13341051 13341051 - GAU: 2821
	Filing Date	2011-12-30
	First Named Inventor	Josep Mumbru
	Art Unit	2821
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	47005-P040WUSC1

	1	1401050	EP		2004-03-24	Filtronic LK Oy		☐
	2	1445821	EP		2004-08-11	Matsushita Electric Industrial Co		☐
	3	2005341313	JP		2005-12-08	Sharp KK		☒
	4	01/54225	WO		2001-07-21	Fractus SA		☐
	5	02/29929	WO		2002-04-11	Marconi Corporation		☐
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	7	2004/068631	WO		2004-08-12	Centurion Wireless Technologies Inc.		☐
	8	2004/102744	WO		2004-11-25	Koninklijke Philips Electronics NV		☐
	9	2004/105182	WO		2004-12-02	Antenova Limited		☐
	10	2005/076409	WO		2005-08-18	Fractus, SA		☐
	11	2006/120250	WO		2006-11-16	Fractus, SA		☐

EFS Web 2.1.17 ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.N./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Art Unit	2821
	Examiner Name	Not Yet Assigned
	Attorney Docket Number	47005-P040WUSC1

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NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T5
	1	FLOWS project - Antenna feasibility study on the printed antenna elements and the multiple input multiple output (MIMO) antenna topologies to be used in Flow mobile terminals, FLOWS project, November 18, 2002	☐
	2	Antenna designs for MIMO systems, Antenova, January 1, 2004	☐
	3	Karaboikis , M. et al, Compact dual-printed inverted-F antenna diversity systems for portable wireless devices, IEEE Antennas and Wireless Propagation Letters, January 1, 2004, Vol. 3	☐
	4	Latif, S. I. et al., Bandwidth enhancement and size reduction of microstrip slot antennas, IEEE Transactions on Antennas and Propagation, March 1, 2005, No. 3, Vol. 53	☐
	5	Mavridis , G. A., A planar two-branch diversity antenna for wireless applications, IEEE Antennas and Propagation Society International Symposium 2006, July 9, 2006	☐
	6	Lindberg , P. et al., Internal active antenna for FM radio reception in mobile handsets, EuCAP, November 8, 2007	☐
	7	Long , S., Rebuttal expert report of Dr. Stuart A. Long (redacted version), Fractus, February 16, 2011	☐
	8	Jaggard , D. L., Rebuttal expert report of Dr. Dwight L. Jaggard (redacted version), Fractus, February 16, 2011	☐
	9	Jaggard , D. L., Expert report of Dwight L. Jaggard (redacted) - expert witness retained by Fractus, Fractus, February 23, 2011	☐

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Examiner Name	Not Yet Assigned
	Attorney Docket Number	47005-P040WUSC1

	10	International search report and the written opinion of the International Searching Authority for PCT/EP2006/007050, EPO, December 13, 2006	☐
	11	Written opinion of the International Searching Authority for PCT/EP2006/007050, EPO, December 13, 2006	☐
	12	Notice of allowance for US patent application 11/988888, USPTO, October 14, 2011	☐
	13	Notice of allowance for US patent application 11/988888, USPTO, July 12, 2011	☐
	14	Amendment in response to non-final office action for US patent application 11/988888, Winstead, May 31, 2011	☐
	15	Office action for US patent application 11/988888, USPTO, January 10, 2011	☐
	16	Office action for US patent application 11/988888, USPTO, November 24, 2010	☐
	17	Amendment and response to restriction requirement for US patent application 11/988888, Winstead, December 17, 2010	☐

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Hoang Nguyen/	Date Considered	06/14/2012

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

EFS Web 2.1.17

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.N./

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	305	antenna with transmit$4 with receiv$3 with (three near3 (frequency or band))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 12:38
L2	158329	antenna with (transmit$4 or receiv$3 or operat$3) with (frequency or band)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 12:38
L3	2311253	ground$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 12:39
L4	160	1 and 2 and 3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 12:39
L5	6562	343/702.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 12:39
L6	29	4 and 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 12:39
L7	2958	antenna with (three near3 (frequency or band))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 12:55
L8	105967	(two or second or dual) near3 antenna	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 12:56
L9	353	3 and 7 and 8 and 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 12:56
L10	3703	3 and 5 and 8	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 13:34
L11	28	1 and 10	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 13:35
L12	1050	antenna with opposite with end with ground$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 13:37

L13	240	5 and 12	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/06/14 13:38

6/14/2012 1:41:04 PM

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13341051	MUMBRU ET AL.
	Examiner	Art Unit
	HOANG V NGUYEN	2821

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	02/17/2012	06/15/2012							
	1	✓	-							
	2	✓	-							
	3	✓	-							
	4	✓	-							
	5	✓	-							
	6	✓	-							
	7	✓	-							
	8	✓	-							
	9	✓	-							
	10	✓	-							
	11	✓	-							
	12	✓	-							
	13	✓	-							
	14	✓	-							
	15	✓	-							
	16	✓	-							
	17	✓	-							
	18	✓	-							
	19	✓	-							
	20	✓	-							
	21		✓							
	22		O							
	23		O							
	24		O							
	25		O							
	26		O							
	27		✓							
	28		O							
	29		O							
	30		✓							
	31		=							
	32		=							
	33		=							
	34		=							
	35		=							
	36		=							

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13341051	MUMBRU ET AL.
	Examiner	**Art Unit**
	HOANG V NGUYEN	2821

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	02/17/2012	06/15/2012							
	37		=							
	38		=							
	39		=							
	40		=							

I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being transmitted via the Office electronic filing system in accordance with 37 CFR § 1.6(a)(4).

Dated: September 14, 2012
Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

Docket No. 47005-P040WUSC1
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Josep Mumbru et al.

Application No. 13/341,051 | Confirmation No. 9540

Filed: December 30, 2011 | Art Unit: 2821

For: HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS | Examiner: H. V. Nguyen

AMENDMENT AFTER FINAL ACTION

MS AF
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Madam:

INTRODUCTORY COMMENTS

In response to the Final Office Action dated June 21, 2012, please amend the above-identified U.S. patent application as indicated herein.

Amendments to the Claims are reflected in the listing of claims which begins on page 2 of this paper.

Remarks/Arguments begin on page 7 of this paper.

AMENDMENTS TO THE CLAIMS

1-20. (Canceled)

21. (Currently Amended) A handheld device comprising:

a substantially rectangular ground plane;

a first antenna capable of transmitting and receiving electromagnetic wave signals in at least three frequency bands used for mobile communication services;

a second antenna capable of operating in at least one frequency band;

~~wherein~~ the first antenna extends in a direction substantially parallel to a first side of the substantially rectangular ground plane;

~~wherein~~ the second antenna extends in a direction substantially parallel to a second side of the substantially rectangular ground plane; ~~and~~

~~wherein~~ the first antenna is arranged near a short side of the substantially rectangular ground plane; and

the first side and the second side are substantially orthogonal.

22. (Previously Presented) The handheld device according to claim 21, wherein said handheld device further comprises at least one slot in the substantially rectangular ground plane, wherein said at least one slot is arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said substantially rectangular ground plane between said feeding points in at least one frequency band corresponding to an operating band of one of said first and second antennas.

23. (Previously Presented) The handheld device according to claim 22, wherein said at least one slot in the substantially rectangular ground plane has an open end in correspondence with a perimeter of said substantially rectangular ground plane.

24. (Previously Presented) The handheld device according to claim 22, wherein said at least one slot has a length of approximately (2N-1)*A/4, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, N>1.

25. (Previously Presented) The handheld device according to claim 21, further comprising at least one conductive strip connected to the substantially rectangular ground plane, wherein said at least one conductive strip is arranged so as to provide a high impedance path in said substantially rectangular ground plane between a feeding point of said first antenna and a feeding point of said second antenna in at least one frequency band corresponding to an operating band of one of said first and second antennas.

26. (Previously Presented) The handheld device according to claim 25, wherein said at least one conductive strip has a length from its connection to the substantially rectangular ground plane, of approximately (2N-1)*A/4, wherein A is a wavelength corresponding to a frequency within said operating band, and N is an integer, N>1.

27. (Previously Presented) The handheld device according to claim 21, wherein the second antenna is arranged to operate in at least one frequency band used for a wireless service in accordance with Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB.

28. (Previously Presented) The handheld device according to claim 21, wherein said handheld device further comprises two or more slots in the substantially rectangular ground plane arranged for providing enhanced isolation between a feeding point of said first antenna and a feeding point of said second antenna by providing a high impedance path in said substantially rectangular ground plane between said feeding points in at least one frequency band corresponding to an operating band of one of said first and second antennas.

29. (Canceled)

30. (Canceled)

31. (Currently Amended) A handheld device comprising:

a printed circuit board including a substantially rectangular ground plane;

a first antenna operating in a plurality of frequency bands, said first antenna being capable of transmitting and receiving electromagnetic wave signals in each frequency band of said plurality of frequency bands;

a second antenna operating in at least a first frequency band, said second antenna being capable of transmitting and receiving electromagnetic wave signals in said first frequency band;

~~wherein~~ the first antenna is arranged substantially close to a short side of the substantially rectangular ground plane;

~~wherein~~ the second antenna is a slot antenna comprising a slot;

~~wherein~~ the first antenna extends in a direction substantially parallel to said short side of the substantially rectangular ground plane;

~~wherein~~ a width of a rectangular area in which the slot antenna is inscribed, divided by a free-space operating wavelength of the slot antenna is smaller than, or equal to, at least one of the following fractions: 1/10, 1/30, 1/50, 1/60, 1/70, or 1/80;

~~wherein~~ a length of the rectangular area in which the slot antenna is inscribed, divided by a free-space operating wavelength of the slot antenna is smaller than, or equal to, at least one of the following fractions: 1/2, 1/3, or 1/4; and

~~wherein~~ the first antenna operates in at least three frequency bands used for mobile communication services.

32. (Previously Presented) The handheld device according to claim 31, wherein the slot antenna is not on a projection area of the first antenna.

33. (Previously Presented) The handheld device according to claim 31, wherein the slot antenna extends in a direction substantially parallel to a long side of the substantially rectangular ground plane.

34. (Previously Presented) The handheld device according to claim 31, wherein the second antenna is arranged to operate in at least one frequency band used for a wireless service in accordance with Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, or DMB.

35. (Currently Amended) A handheld device comprising:

a printed circuit board including a substantially rectangular ground plane;

a first antenna operating in a plurality of frequency bands, said first antenna being capable of transmitting and receiving electromagnetic wave signals in each frequency band of said plurality of frequency bands;

a second antenna operating in at least one frequency band;

~~wherein~~ the second antenna comprises a slot;

~~wherein~~ the first antenna extends in a direction substantially parallel to a first side of the substantially rectangular ground plane;

~~wherein~~ the second antenna extends in a direction substantially parallel to a second side of the substantially rectangular ground plane; and

~~wherein~~ the second antenna is not on a projection area of the first antenna.

36. (Previously Presented) The handheld device of claim 35, wherein the first antenna comprises a non-conducting material provided under at least 50% of a projection area of the first antenna.

37. (Previously Presented) The handheld device of claim 35, wherein the at least one frequency band is different from any frequency band of the plurality of frequency bands.

38. (Previously Presented) The handheld device of claim 35, wherein the first side and the second side are substantially orthogonal.

39. (Previously Presented) The handheld device of claim 35, wherein the second antenna is printed as a conductive layer on the printed circuit board or is etched from a conductive layer of the printed circuit board.

40. (Previously Presented) The handheld device according to claim 35, wherein the second antenna is embedded in an SMT component.

41. (New) The handheld device according to claim 21, wherein the second antenna is arranged to operate in at least one frequency band used for a mobile communication service.

42. (New) The handheld device according to claim 21, wherein the second antenna is selected from the group consisting of monopole antenna, PIFA, IFA, or patch antenna.

REMARKS

Claims 21-28 and 31-42 are now pending in this application. Claims 21, 31, and 35 have been amended. Claims 29-30 have been canceled. New claims 41-42 have been added. Applicant respectfully submits that no new matter has been added. Applicant respectfully requests reconsideration of this application and favorable action on all pending claims.

Claims 31-40 have been indicated as allowed. Claims 22-26 and 28-29 stand objected to as being dependent upon a rejected base claim, but have been indicated to be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. Applicant appreciates the Examiner's indication of allowable subject matter.

I. Rejection under 35 U.S.C. § 102

Claims 21, 27, and 30 stand rejected under 35 U.S.C. 102(b) as being anticipated by U.S. Patent No. 7,193,571 to Inatsugu et al. ("Inatsugu"). Claim 30 has been canceled, thus rendering the rejection thereof moot.

Independent claim 21 relates to a handheld device. Applicant has amended independent claim 21 to include the features of dependent claim 29. Claim 29 has been indicated by the Examiner to represent allowable subject matter.

Claims 27 depends from and further restricts independent claim 21 in a patentable sense. This dependent claim is therefore deemed to distinguish over Inatsugu for at least the same reasons as those set forth above relative to the rejection of independent claim 21. Withdrawal of the rejection of dependent claim 27 is thus respectfully requested.

New claims 41-42 depend from and further restrict independent claim 21 in a patentable sense. Applicant respectfully submits that, for at least the reasons set forth above with respect to independent claim 21, dependent claims 41-42 are in condition for allowance.

In view of the above, Applicant respectfully submits that the present application is in condition for allowance. A Notice to that effect is respectfully requested.

Dated: September 14, 2012

Respectfully submitted,

Electronic signature: /Shoaib A. Mithani/
Shoaib A. Mithani
Registration No.: 61,654
WINSTEAD PC
P.O. Box 131851
Dallas, Texas 75313
(214) 745-5400
Attorneys For Applicant

Electronic Acknowledgement Receipt

EFS ID:	13743785
Application Number:	13341051
International Application Number:	
Confirmation Number:	9540
Title of Invention:	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
First Named Inventor/Applicant Name:	Josep Mumbru
Customer Number:	61060
Filer:	Shoaib Amirali Mithani
Filer Authorized By:	
Attorney Docket Number:	47005-P040WUSC1
Receipt Date:	14-SEP-2012
Filing Date:	30-DEC-2011
Time Stamp:	09:58:33
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Amendment After Final	47005P040Amendment.pdf	36732 6d0bbf48a0fe6b9f4cca6b8740d5719b472dffba	no	8

Warnings:	
Information:	

Total Files Size (in bytes):	36732

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number	Filing Date	☐ To be Mailed
13/341,051	12/30/2011	

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)	SMALL ENTITY ☐		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =		OR	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =			X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	09/14/2012	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X $ =		OR	X $60=	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X $ =		OR	X $250=	0
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)	OR	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =		OR	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =		OR	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))									
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/RAMONA WILSON/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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NOTICE OF ALLOWANCE AND FEE(S) DUE

61060 7590 09/24/2012

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

EXAMINER	
NGUYEN, HOANG V	
ART UNIT	PAPER NUMBER
2821	

DATE MAILED: 09/24/2012

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/341,051	12/30/2011	Josep Mumbru	47005-P040WUSC1	9540

TITLE OF INVENTION: HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1740	$300	$0	$2040	12/24/2012

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (Rev. 02/11)

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

61060 7590 09/24/2012

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/341,051	12/30/2011	Josep Mumbru	47005-P040WUSC1	9540

TITLE OF INVENTION: HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1740	$300	$0	$2040	12/24/2012

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, HOANG V	2821	343-702000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): (**Please first reapply any previously paid issue fee shown above**)

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/341,051	12/30/2011	Josep Mumbru	47005-P040WUSC1	9540

61060 7590 09/24/2012

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EXAMINER	
NGUYEN, HOANG V	
ART UNIT	PAPER NUMBER
2821	

DATE MAILED: 09/24/2012

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 02/11)

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No.	Applicant(s)	
	13/341,051	MUMBRU ET AL.	
	Examiner	Art Unit	
	HOANG V. NGUYEN	2821	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *after final amendment filed on 9/14/2012*.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *21-28 and 31-42*.
4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☒ All b) ☐ Some* c) ☐ None of the:
      1. ☒ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
6. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☒ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

/HOANG V NGUYEN/
Primary Examiner, Art Unit 2821

Examiner's Amendment

1. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Mr. Shoaib Mithani on 9/17/2012.

2. The application has been amended as follows:

Claim 21, line 3, cancel [capable of transmitting and receiving] and insert - - configured to transmit and receive - - in place thereof.

Claim 21, line 5, cancel [capable of operating] and insert - - configured to operate - - in place thereof.

Claim 31, lines 3-4, cancel [being capable of transmitting and receiving] and insert - - configured to transmit and receive - - in place thereof.

Claim 31, lines 6-7, cancel [being capable of transmitting and receiving] and insert - - configured to transmit and receive - - in place thereof.

Claim 35, lines 3-4, cancel [being capable of transmitting and receiving] and insert - - configured to transmit and receive - - in place thereof.

The examiner's amendment was done in order to obviate relative terms that might render the claims indefinite.

Allowable Subject Matter

3. Claims 21-28 and 31-42 are allowed.

4. The following is an examiner's statement of reasons for allowance:

Regarding claim 21, Inatsugu et al (US 7,193,571 B2) discloses a handheld device comprising a substantially rectangular ground plane; a first antenna capable of transmitting and receiving electromagnetic wave signals in at least three frequency bands used for mobile communication services; a second antenna capable of operating in at least one frequency band; in the first antenna extends in a direction substantially parallel to a first side of the substantially rectangular ground plane; the second antenna extends in a direction substantially parallel to a second side of the substantially rectangular ground plane; and the first antenna is arranged near a short side of the substantially rectangular ground plane. Inatsugu, however, fails to further teach that the first side and the second side are substantially orthogonal.

Claims 22-28, 41 and 42 are allowed for depending on claim 21.

Reasons for indicating allowable subject matter for claims 31-40 were provided in the previous office action.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Inquiry

Any inquiry concerning this communication or earlier communications from the examiner should be directed to HOANG V. NGUYEN whose telephone number is (571)272-1825. The examiner can normally be reached on Mondays-Fridays from 9:00 a.m. to 5:00 p.m..

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jacob Y. Choi can be reached on (571) 272-2367. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/HOANG V NGUYEN/
Primary Examiner, Art Unit 2821

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	308	antenna with transmit$4 with receiv$3 with (three near3 (frequency or band))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:39
L2	146209	antenna with (transmit$4 or receiv$3 or opert$3) with (frequency or band)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:40
L3	2345335	ground$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:40
L4	163	1 and 2 and 3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:40
L5	6703	343/702.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:40
L6	29	4 and 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:40
L7	3010	antenna with (three near3 (frequency or band))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:41
L8	108936	(two or second or dual) near3 antenna	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:41
L9	362	3 and 5 and 7 and 8	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:42
L10	1164	(first adj antenna) with (perpendicular$3 or normal or orthogonal) with (second adj antenna)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:44
L11	154	5 and 10	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/09/18 08:44

9/18/2012 8:52:31 AM

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

BIB DATA SHEET

CONFIRMATION NO. 9540

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
13/341,051	12/30/2011	343	2821	47005-P040WUSC1

APPLICANTS

Josep Mumbru, Barcelona, SPAIN;
Jaume Anguera, Castellon, SPAIN;
Jordi Soler, Girona, SPAIN;
Carles Puente, Barcelona, SPAIN;

**** CONTINUING DATA ***************************

This application is a CON of 11/988,888 09/30/2008 PAT 8,115,686 /HN/
which is a 371 of PCT/EP2006/007050 07/18/2006
which claims benefit of 60/702,205 07/25/2005

**** FOREIGN APPLICATIONS ***************************

EUROPEAN PATENT OFFICE (EPO) 05106694.2 07/21/2005 /HN/

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****

01/12/2012

Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /HOANG V NGUYEN/ Examiner's Signature	☐ Met after Allowance HN Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		SPAIN	23	20	3

ADDRESS

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313
UNITED STATES

TITLE

HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS

FILING FEE RECEIVED		
1250	FEES: Authority has been given in Paper No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13341051	MUMBRU ET AL.
	Examiner	**Art Unit**
	HOANG V NGUYEN	2821

ORIGINAL		INTERNATIONAL CLASSIFICATION										
CLASS	SUBCLASS	CLAIMED					NON-CLAIMED					
343	702	H	0	1	Q	1 / 24 (2006.0)						
CROSS REFERENCE(S)		H	0	1	Q	1 / 48 (2006.01.01)						
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)											
343	846											

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
	1		17	11	33										
	2		18	12	34										
	3		19	13	35										
	4		20	14	36										
	5	1	21	15	37										
	6	2	22	16	38										
	7	3	23	17	39										
	8	4	24	18	40										
	9	5	25	19	41										
	10	6	26	20	42										
	11	7	27												
	12	8	28												
	13		29												
	14		30												
	15	9	31												
	16	10	32												

NONE (Assistant Examiner) (Date)	**Total Claims Allowed:** 20	
/HOANG V NGUYEN/ Primary Examiner.Art Unit 2821 09/18/2012 (Primary Examiner) (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 4a

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13341051	MUMBRU ET AL.
	Examiner	Art Unit
	HOANG V NGUYEN	2821

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	02/17/2012	06/15/2012	09/18/2012						
	1	✓	-	-						
	2	✓	-	-						
	3	✓	-	-						
	4	✓	-	-						
	5	✓	-	-						
	6	✓	-	-						
	7	✓	-	-						
	8	✓	-	-						
	9	✓	-	-						
	10	✓	-	-						
	11	✓	-	-						
	12	✓	-	-						
	13	✓	-	-						
	14	✓	-	-						
	15	✓	-	-						
	16	✓	-	-						
	17	✓	-	-						
	18	✓	-	-						
	19	✓	-	-						
	20	✓	-	-						
1	21		✓	=						
2	22		O	=						
3	23		O	=						
4	24		O	=						
5	25		O	=						
6	26		O	=						
7	27		✓	=						
8	28		O	=						
	29		O	-						
	30		✓	-						
9	31		=	=						
10	32		=	=						
11	33		=	=						
12	34		=	=						
13	35		=	=						
14	36		=	=						

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13341051	MUMBRU ET AL.
	Examiner	Art Unit
	HOANG V NGUYEN	2821

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	02/17/2012	06/15/2012	09/18/2012						
15	37		=	=						
16	38		=	=						
17	39		=	=						
18	40		=	=						
19	41			=						
20	42			=						

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13341051	MUMBRU ET AL.
	Examiner	Art Unit
	HOANG V NGUYEN	2821

SEARCHED			
Class	Subclass	Date	Examiner
343	702, 700MS, 846, 767	6/1/124	HN
343	702, 700MS, 846, 848, 767	9/18/12	HN

SEARCH NOTES		
Search Notes	Date	Examiner
EAST	6/14/12	HN
Inventor name search	6/1/124	HN
EAST	9/18/12	HN

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner
343	702, 846	9/18/12	HN

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

61060 7590 09/24/2012
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/341,051	12/30/2011	Josep Mumbru	47005-P040WUSC1	9540

TITLE OF INVENTION: HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1740	$300	$0	$2040	12/24/2012

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, HOANG V	2821	343-702000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
1 Winstead PC
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Fractus, S.A.
(B) RESIDENCE: (CITY and STATE OR COUNTRY): Barcelona, Spain

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
☒ Issue Fee
☒ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number 232426 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.
☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature Stanley R. Moore
Typed or printed name Stanley R. Moore
Date December 18 2012
Registration No. 26,958

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Electronic Patent Application Fee Transmittal

Application Number:	13341051
Filing Date:	30-Dec-2011
Title of Invention:	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
First Named Inventor/Applicant Name:	Josep Mumbru
Filer:	Ross Robinson/Brenda Brown
Attorney Docket Number:	47005-P040WUSC1

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Publ. Fee- early, voluntary, or normal	1504	1	300	300
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl issue fee	1501	1	1770	1770

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**2070**

Electronic Acknowledgement Receipt	
EFS ID:	14502589
Application Number:	13341051
International Application Number:	
Confirmation Number:	9540
Title of Invention:	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
First Named Inventor/Applicant Name:	Josep Mumbru
Customer Number:	61060
Filer:	Ross Robinson/Brenda Brown
Filer Authorized By:	Ross Robinson
Attorney Docket Number:	47005-P040WUSC1
Receipt Date:	18-DEC-2012
Filing Date:	30-DEC-2011
Time Stamp:	15:55:46
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$2070
RAM confirmation Number	3293
Deposit Account	232426
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	Issue_Fee_Transmittal_47005_P040WUSC1_1.PDF	64874 75c81e5c454752506b75adffe3808c3c0cc8caa1	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	32013 0514ba8ba1c6dce165ace1fc221a1ad296628c39	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	96887		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/341,051	01/29/2013	8362960	47005-P040WUSC1	9540

61060 7590 01/09/2013

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Josep Mumbru, Barcelona, SPAIN;
Jaume Anguera, Castellon, SPAIN;
Jordi Soler, Girona, SPAIN;
Carles Puente, Barcelona, SPAIN;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

REVOCATION OF POWER OF ATTORNEY
AND NEW POWER OF ATTORNEY BY ASSIGNEE
AND STATEMENT UNDER 37 C.F.R. §3.73(c) (pre-AIA §3.73(b))

The Assignee of the entire right, title, and interest in the applications identified in the attached Schedule A hereby revoke all previously granted powers of attorney given in said applications and grant the registered practitioners of EDELL, SHAPIRO & FINNAN, LLC included in the Customer Number provided below, power to act, prosecute, and transact all business in the U.S. Patent and Trademark Office in connection with said applications, any applications claiming priority to said applications, and any patents issuing therefrom.

The Assignee certifies that to the best of his knowledge and belief, it is the owner of the entire right, title, and interest in said applications as evidenced by assignment previously recorded in the U.S. Patent and Trademark Office as listed in Schedule A.

Please direct all correspondence concerning the applications to:

EDELL, SHAPIRO & FINNAN, LLC
9801 Washingtonian Boulevard, Suite 750
Gaithersburg, MD 20878
(301) 424-3640

CUSTOMER NUMBER: 27896

The undersigned (whose titles are supplied below) are empowered to sign this statement on behalf of the Assignee.

Date: 9 March 2022

Signature: _____

Name: Ruben Bonet
Title: President and CEO
Company: Fractus, S.A.

SCHEDULE A

Application Number	Application Date	Title	Patent Number	Grant Date	Status	Reference
11/021597	12/23/2004	Multiband antenna for handheld terminal	US7486242	2/3/2009	Granted	016875/0195
12/246964	10/7/2008	Antenna with one or more holes (Multihole antenna)	US7907092	15/03/2011	Granted	021807/0618
11/033788	1/12/2005	Notched-fed antenna	US7342553	3/11/2008	Granted	016169/0040
11/075980	3/9/2005	Coupled multiband antennas	US7315289	1/1/2008	Granted	016596/0954
11/040622	1/21/2005	Integrated circuit package including miniature antenna	US7095372	8/22/2006	Granted	016731/0090
11/713324	3/2/2007	Multiband monopole antenna for a mobile communications device	US7403164	22/07/2008	Granted	016977/0289
12/055748	3/26/2008	Multiband monopole antenna for a mobile communications device	US7675470	3/9/2010	Granted	020739/0497
12/652974	1/6/2010	Multiband monopole antenna for a mobile communications device	US8253633	28/08/2012	Granted	023760/0594
13/029382	17/02/2011	Multiband monopole antenna for a mobile communications device	US8259016	9/4/2012	Granted	025984/0841
12/364066	2/2/2009	Miniature antenna having a volumetric structure	US8149171	4/3/2012	Granted	022374/0808
13/400895	2/21/2012	Miniature antenna having a volumetric structure	US8593349	26/11/2013	Granted	027767/0576
10/584442	18/07/2006	Multiband monopole antennas for mobile communications devices	US7423592	9/9/2008	Granted	017963/0702
12/228487	13/08/2008	Multiband monopole antennas for mobile communications devices	US8456365	6/4/2013	Granted	021687/0563
10/587119	29/08/2006	Multiband monopole antennas for mobile network communication	US7417588	26/08/2008	Granted	019729/0761
10/588640	9/8/2006	Handset with electromagnetic bra	US7456792	25/11/2008	Granted	019768/0631
11/556455	11/3/2006	Radio frequency system in package including antenna	US7791539	9/7/2010	Granted	018479/0606
11/719151	13/06/2007	Antenna structure for a wireless device with a ground plane shaped	US7782269	24/08/2010	Granted	019420/0993
11/793406	7/19/2007	Shaped ground plane for radio apparatus	US7932863	4/26/2011	Granted	019581/0966

Application Number	Application Date	Title	Patent Number	Grant Date	Status	Reel/Frame
11/886980	3/13/2009	Antenna contacting assembly	US8193998	6/5/2012	Granted	022396/0792
11/921537	2/8/2008	Wireless implantable medical device	US8565891	10/22/2013	Granted	020716/0622
11/988888	9/30/2008	Handheld device with two antennas and method of	US8115686	2/14/2012	Granted	021614/0677
13/341051	12/30/2011	Handheld device with two antennas and method of	US8362960	1/29/2013	Granted	027612/0782
13/718348	12/18/2012	Handheld device with two antennas and method of	US8810458	8/19/2014	Granted	029739/0546
11/884991	9/20/2007	Slotted ground plane used as a slot antenna or used for a pifa antenna	US7872605	1/18/2011	Granted	019852/0289
12/958522	12/2/2010	Slotted ground plane used as a slot antenna or used for a pifa antenna	US8111199	2/7/2012	Granted	025601/0698
13/336127	12/23/2011	Slotted ground plane used as a slot antenna or used for a pifa antenna	US8593360	11/26/2013	Granted	027520/0274
12/226024	11/14/2008	Wireless portable device including internal broadcast receiver	US8472908	6/25/2013	Granted	021844/0974
12/308417	1/16/2009	Chip module, SIM card, wireless device and wireless	US8196829	6/12/2012	Granted	022120/0270

Electronic Acknowledgement Receipt

EFS ID:	45303052
Application Number:	13341051
International Application Number:	
Confirmation Number:	9540
Title of Invention:	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
First Named Inventor/Applicant Name:	Josep Mumbru
Customer Number:	61060
Filer:	Mark James DeBoy/Janet Dorgan
Filer Authorized By:	Mark James DeBoy
Attorney Docket Number:	47005-P040WUSC1
Receipt Date:	23-MAR-2022
Filing Date:	30-DEC-2011
Time Stamp:	17:59:12
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	FRACTUS_POA_WithScheduleA-Signed.pdf	458111 6571535611c8ca82245ce93ed0f54c3cb4d341f2	no	3

Warnings:

Information:	
Total Files Size (in bytes):	458111

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/341,051	12/30/2011	Josep Mumbru	47005-P040WUSC1

CONFIRMATION NO. 9540

27896
EDELL, SHAPIRO & FINNAN, LLC
9801 Washingtonian Blvd.
Suite 750
Gaithersburg, MD 20878

POA ACCEPTANCE LETTER

OC000000132707522

Date Mailed: 03/28/2022

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 03/23/2022.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/atesfai/

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Alexandria, Virginia 22313-1450
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/341,051	12/30/2011	Josep Mumbru	47005-P040WUSC1

CONFIRMATION NO. 9540

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313-1851

POWER OF ATTORNEY NOTICE

OC000000132707465

Date Mailed: 03/28/2022

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 03/23/2022.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/atesfai/