PTO/AIA/15 (07-12)
Approved for use through 01/31/2014. 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.

UTILITY PATENT APPLICATION TRANSMITTAL

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

Attorney Docket No.	47005-P040WUSC2
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.** (PTO/SB/17 or equivalent)
2. [ ] **Applicant claims small entity status.** See 37 CFR 1.27.
3. [X] **Specification.** [*Total Pages* 52]
   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. **Inventor's Oath or Declaration.** [*Total Sheets*]
   (including substitute statements under 37 CFR 1.64 and assignments serving as an oath or declaration under 37 CFR 1.63(e))
   a. [ ] Newly executed (original or copy)
   b. [ ] A copy from a prior application (37 CFR 1.63(d))
6. [X] **Application Data Sheet**. **See note below*
   See 37 CFR 1.76 (PTO/AIA/14 of equivalent)
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
Alexandria, VA 22313-1450

ACCOMPANYING APPLICATION PARTS

9. [ ] **Assignment Papers** (cover sheet & document(s))
   Name of Assignee
10. [ ] **37 CFR 3.73(c) 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:

***Note:** (1) Benefit claims under 37 CFR 1.78 and foreign priority claims under 1.55 **must** be included in an Application Data Sheet (ADS).
(2) For applications filed under 35 U.S.C. 111, the application must contain an ADS specifying the applicant if the applicant is an assignee, person to whom the inventor is under an obligation to assign, or person who otherwise shows sufficient proprietary interest in the matter. See 37 CFR 1.46(b).

19. CORRESPONDENCE ADDRESS

[X] The address associated with Customer Number: 61060 ***OR*** [ ] Correspondence address below

Name					
Address					
City		State		Zip Code	
Country		Telephone		Email	

Signature	/Shoaib A. Mithani/	Date	December 18, 2012
Name (Print/Type)	Shoaib A. Mithani	Registration No. (Attorney/Agent)	61,654

5973121v.1 47005/P040WUSC2

Geotab Exhibit 1002
Geotab v. Fractus

Application Data Sheet

Inventor Information

Inventor Number::	1
Given Name::	Josep
Family Name::	Mumbru
City of Residence::	Barcelona
Country of Residence::	Spain
Street of mailing address::	Consell de Cent, 322
City of mailing address::	Barcelona
Country of mailing address::	Spain
Postal or Zip Code of mailing address::	08007

Inventor Number::	2
Given Name::	Jaume
Family Name::	Anguera
City of Residence::	Castellon
Country of Residence::	Spain
Street of mailing address::	Paseo Blasco Ibañez
	15-2, Vinaros
City of mailing address::	Castellon
Country of mailing address::	Spain
Postal or Zip Code of mailing address::	E-12500

Inventor Number::	3
Given Name::	Jordi
Family Name::	Soler
City of Residence::	Mataro
Country of Residence::	Spain
Street of mailing address::	Fray Luis de Leon
	19-21 Atico
City of mailing address::	Mataro
Country of mailing address::	Spain
Postal or Zip Code of mailing address::	E-08302

Inventor Number::	4
Given Name::	Carles
Family Name::	Puente
City of Residence::	Sant Cugat del Valles
Country of Residence::	Spain
Street of mailing address::	Verdi, 45
City of mailing address::	Sant Cugat del Valles
Country of mailing address::	Spain
Postal or Zip Code of mailing address::	08172

Correspondence Information

Correspondence Customer Number::	61060

Application Information

Application Type::	Regular
Subject Matter::	Utility
CD-ROM or CD-R?::	None
Sequence submission?::	None
Computer Readable Form (CRF)?::	No
Title::	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
Attorney Docket Number::	47005-P040WUSC2
Request for Early Publication?::	No
Request for Non-Publication?::	No
Small Entity?::	No
Petition included?::	No
Secrecy Order in Parent Appl.?::	No
Authorization to Permit Access::	No

Representative Information

Domestic Priority Information

Application::	Continuity Type::	Parent Application::	Parent Filing Date::
This Application	Continuation of	13/341,051	12/30/11
13/341,051	Continuation of	11/988888	09/30/08
11/988888	National Stage of	PCT/EP2006/007050	07/18/06
PCT/EP2006/007050	Provisional Priority under 35 U.S.C. 119(e)	60/702,205	07/25/05

Foreign Priority Information

Country::	Application number::	Filing Date::	Priority Claimed::
European Patent Office	05106694.2	07/21/05	Yes

Applicant Information

Applicant Number::	1
Applicant Type::	Assignee
Organization Name::	Fractus, S.A.
Street of mailing address::	Alcalde Barnils, 64-68
	Modul C, 3rd Floor
City of mailing address::	Sant Cugat del Valles
Country of mailing address::	Spain
Postal or Zip Code of mailing address::	08174

Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.			
Signature	/Shoaib A. Mithani/	Date	December 18, 2012
Name (Print/Type)	Shoaib A. Mithani	Registration No. (Attorney/Agent)	61,654

Application No. (if known): Attorney Docket No.: 47005-P040WUSC2

Certificate of Electronic Filing Under 37 C.F.R. § 1.8

I hereby certify that this correspondence is being transmitted via the Office electronic filing system in accordance with 37 C.F.R. § 1.6(a)(4):

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

on December 18, 2012 .
Date

/Shoaib A. Mithani/
Signature

Shoaib A. Mithani
Typed or printed name of person signing Certificate

61,654
Registration Number, if applicable

(214) 745-5403
Telephone Number

Note: Each paper must have its own certificate of mailing.

Application Data Sheet (5 pages)

5974102v.1 47005/P040WUSC2

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-P040WUSC2
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	390	390
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($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1260**

Electronic Acknowledgement Receipt	
EFS ID:	14501853
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	18-DEC-2012
Filing Date:	
Time Stamp:	15:30:20
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$1260
RAM confirmation Number	2595
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 1.16 (National application filing, search, and examination fees) Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)	

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)

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	Preliminary Amendment	Amendment_1.pdf	35668 0207dee5019111e1fbf0781615412f44844c cbaf	no	8
Warnings:					
Information:					
2		Application_3.pdf	14121393 f6e05a0623403c4152039d13fe689b7bfdc7 bff6	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	Transmittal of New Application	Transmittal_4.pdf	33262 aba8ad8acbdce6e5731ac786f72715867a2 57632	no	1
Warnings:					
Information:					
4	Application Data Sheet	47005ADS.pdf	22712 b2591128711e6981b60014928c28fa99d91 ec2ef	no	6
Warnings:					
Information:					
This is not an USPTO supplied ADS fillable form					
5	Fee Worksheet (SB06)	fee-info.pdf	33303 7ca943bdc9598dd9a3dc46b1e491c87f5e9 932cd	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	14246338		

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 37 CFR § 1.6(a)(4).

Dated: December 18, 2012
Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

Docket No. 47005-P040WUSC2
(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: 2821

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

Examiner: H. V. Nguyen

FIRST PRELIMINARY AMENDMENT

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

Dear Madam:

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.

Amendments to the Claims are reflected in the listing of claims which begins on page 3 of this paper.

Remarks/Arguments begin on page 8 of this paper.

AMENDMENTS TO THE SPECIFICATION

Please add the following at after the Title of the invention:

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application is a continuation application of U.S. Patent Application No. 13/341,051. U.S. Patent Application No. 13/341,051 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 Internationa 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, whichwas 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. 13/341,051, 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.

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;

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;

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. (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) 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;

the first antenna is arranged substantially close to a short side of the substantially rectangular ground plane;

the second antenna is a slot antenna comprising a slot;

the first antenna extends in a direction substantially parallel to said short side of the substantially rectangular ground plane;

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;

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

the first antenna operates in at least three frequency bands used for mobile communication services.

30. (NEW) The handheld device according to claim 29, wherein the slot antenna is not on a projection area of the first antenna.

31. (NEW) The handheld device according to claim 29, wherein the slot antenna extends in a direction substantially parallel to a long side of the substantially rectangular ground plane.

32. (NEW) The handheld device according to claim 39, 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.

33. (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;

the second antenna comprises a slot;

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 second antenna is not on a projection area of the first antenna.

34. (NEW) The handheld device of claim 33, wherein the first antenna comprises a non-conducting material provided under at least 50% of a projection area of the first antenna.

35. (NEW) The handheld device of claim 33, wherein the at least one frequency band is different from any frequency band of the plurality of frequency bands.

36. (NEW) The handheld device of claim 33, wherein the first side and the second side are substantially orthogonal.

37. (NEW) The handheld device of claim 33, 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.

38. (NEW) The handheld device according to claim 33, wherein the second antenna is embedded in an SMT component.

39. (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.

40. (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

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 18, 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

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;

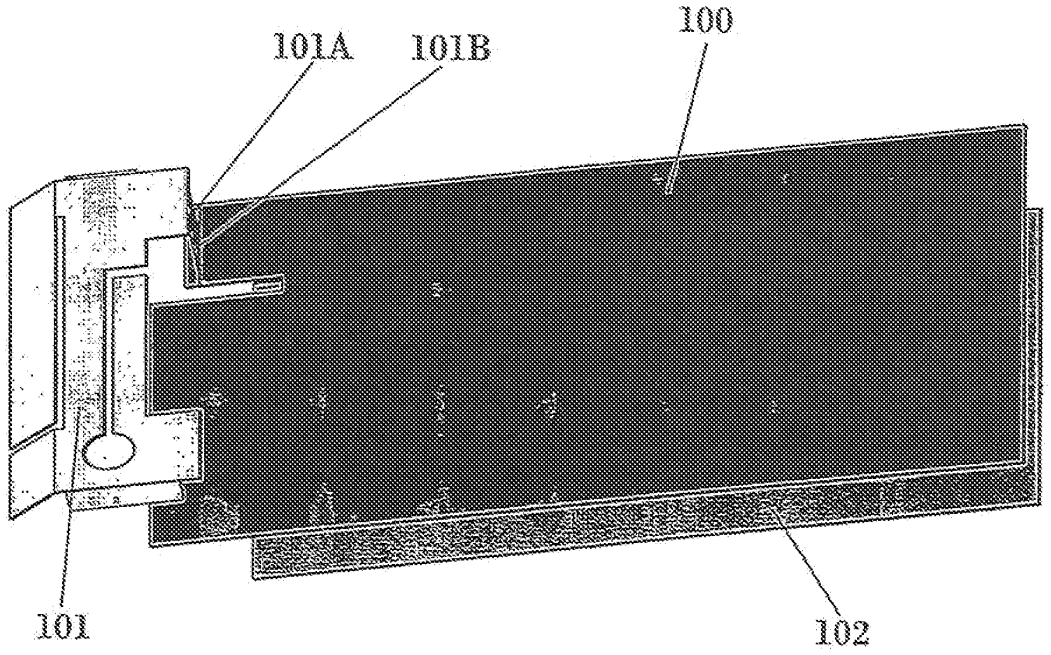
the second antenna operating in a first frequency band, wherein the first frequency band is different from any frequency band of the plurality of frequency bands;

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

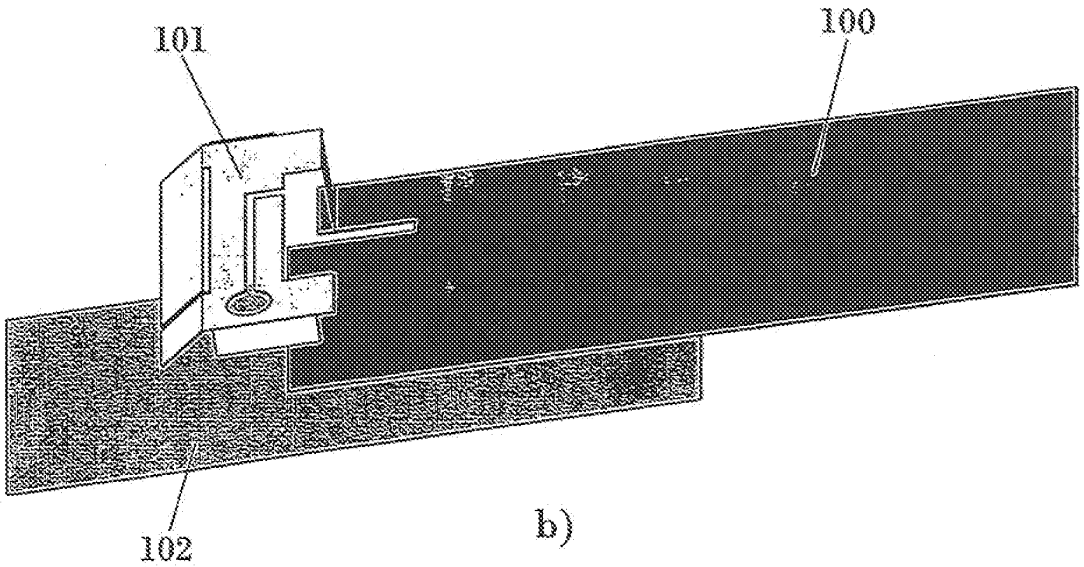
providing a high impedance path in said ground-plane between said feeding points at at least one frequency band selected from said plurality of frequency bands and the first frequency band.

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)

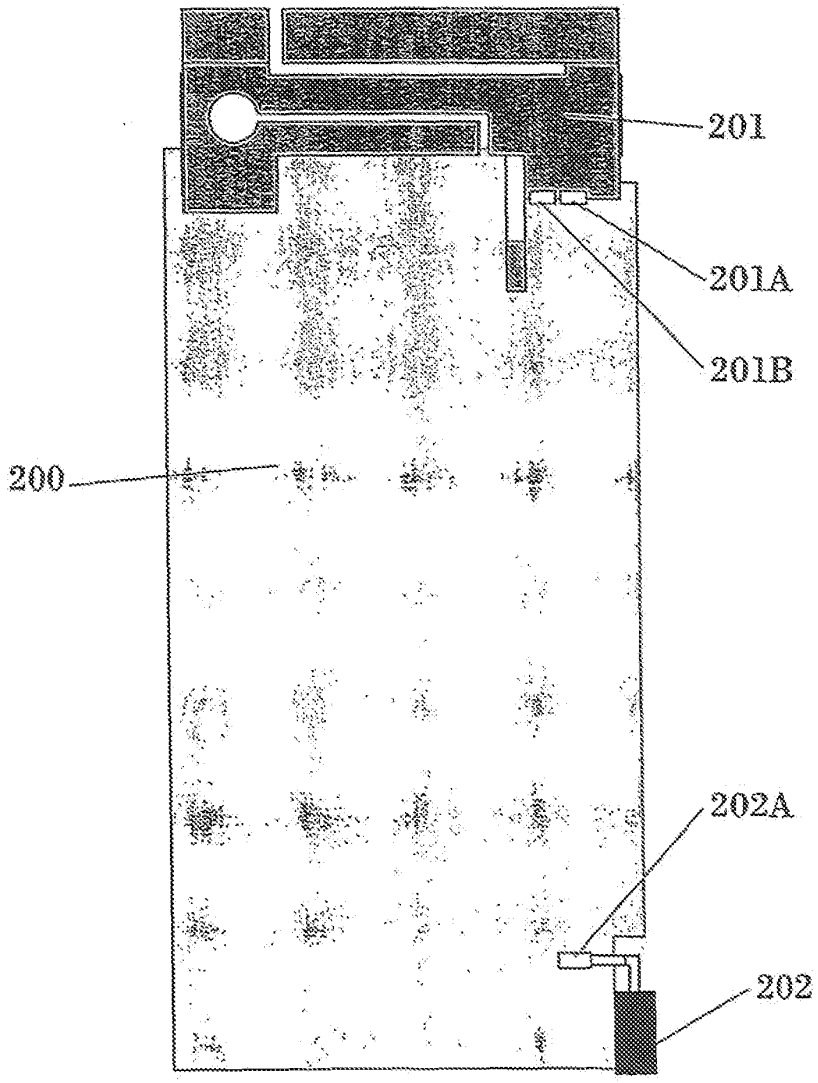
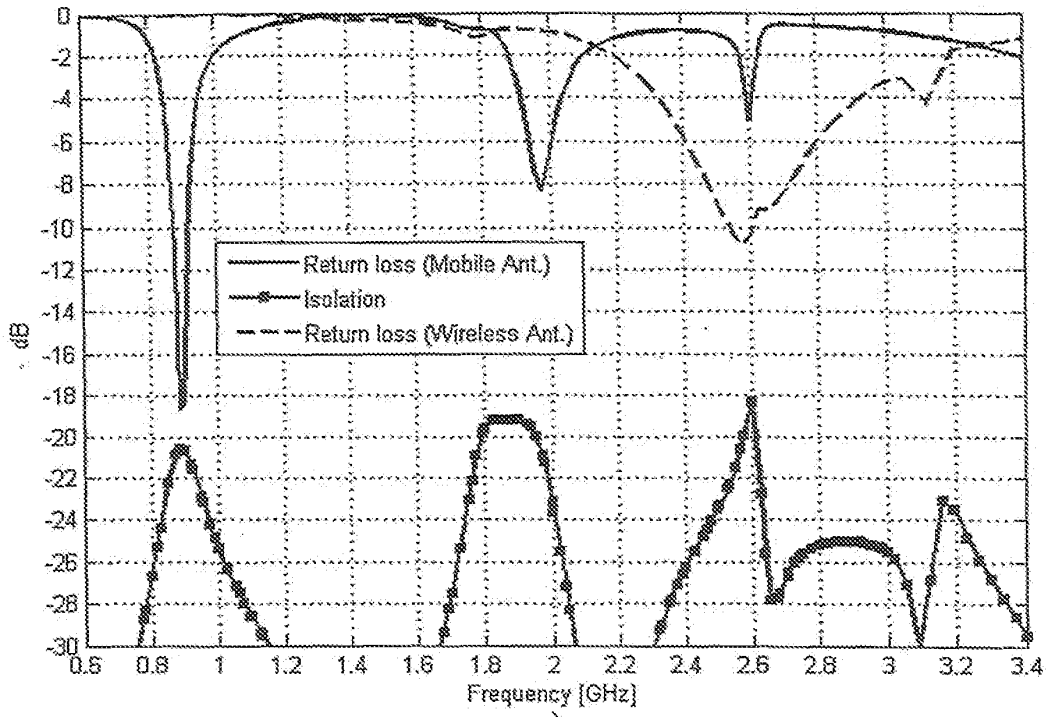
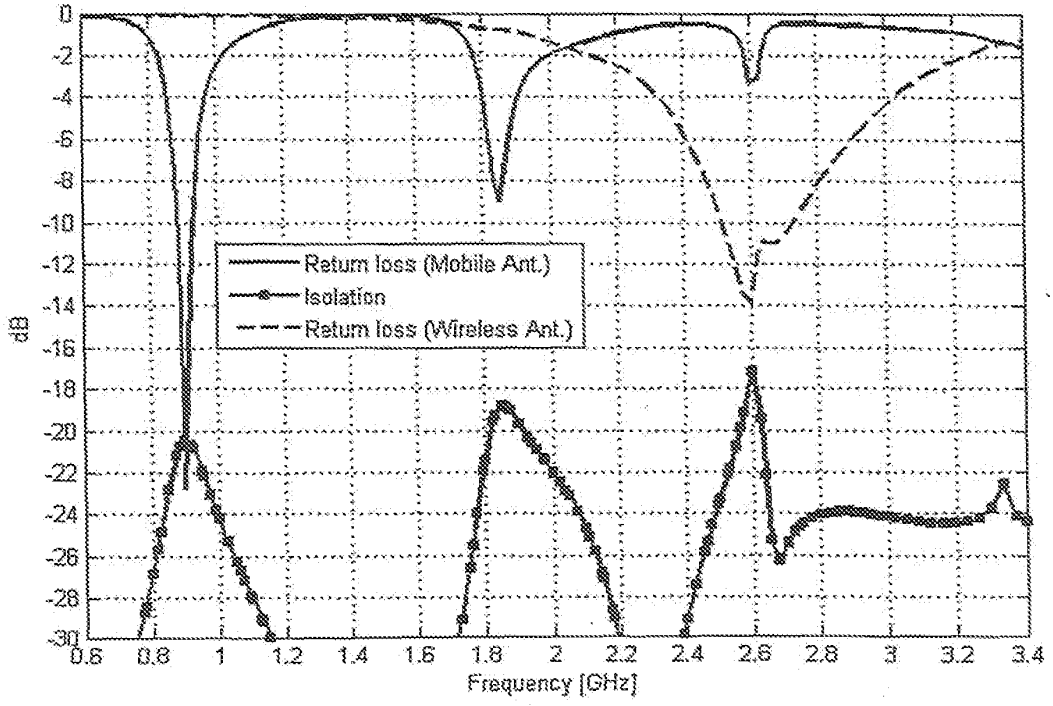


FIG. 2
(PRIOR ART)



a)



b)

FIG. 3
(PRIOR ART)

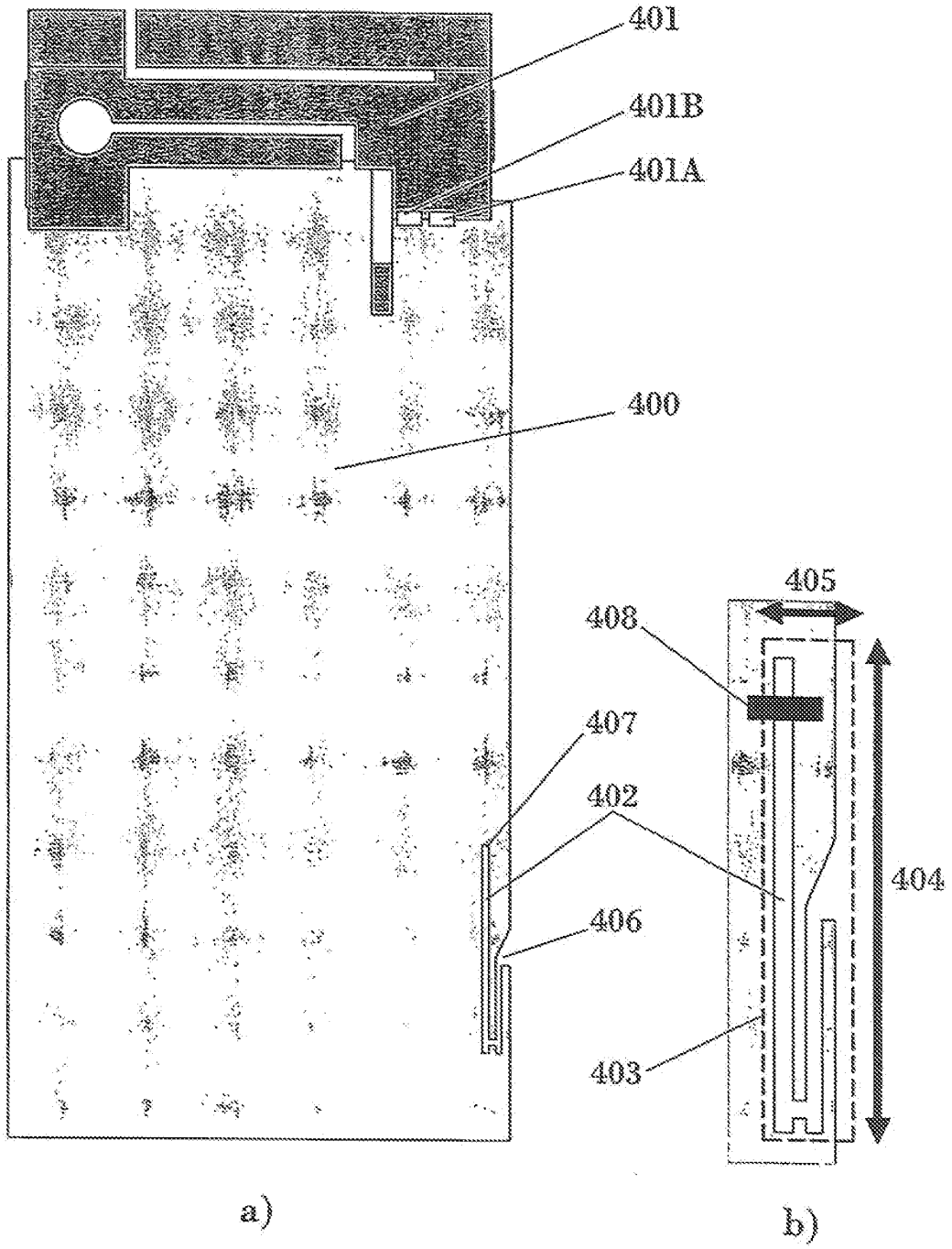
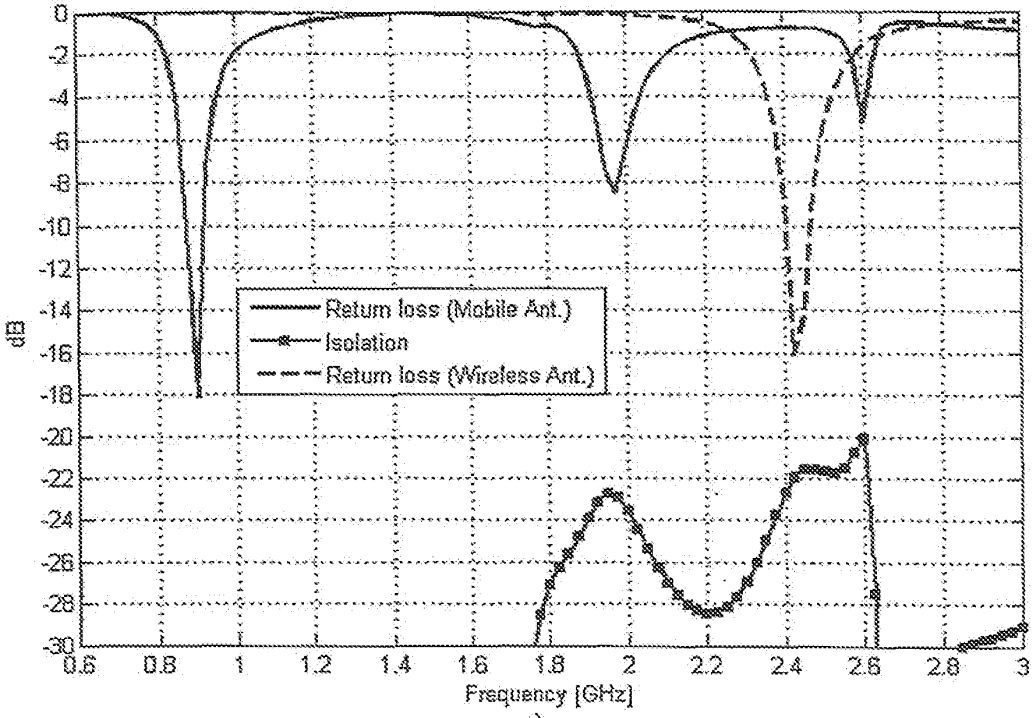
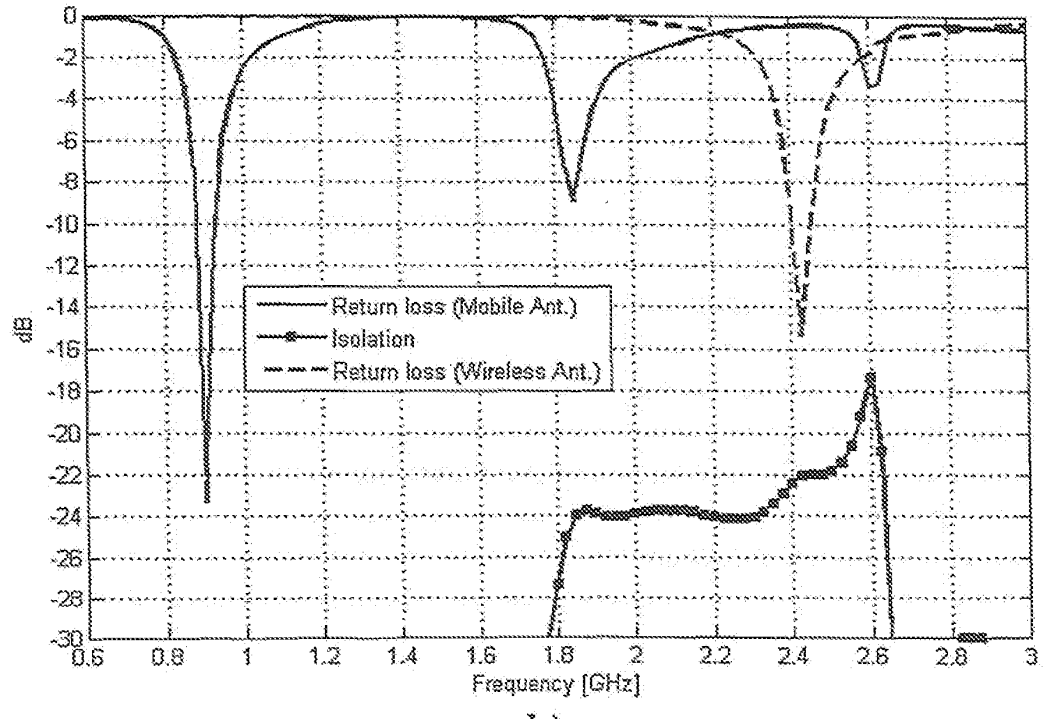


FIG. 4


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. 5

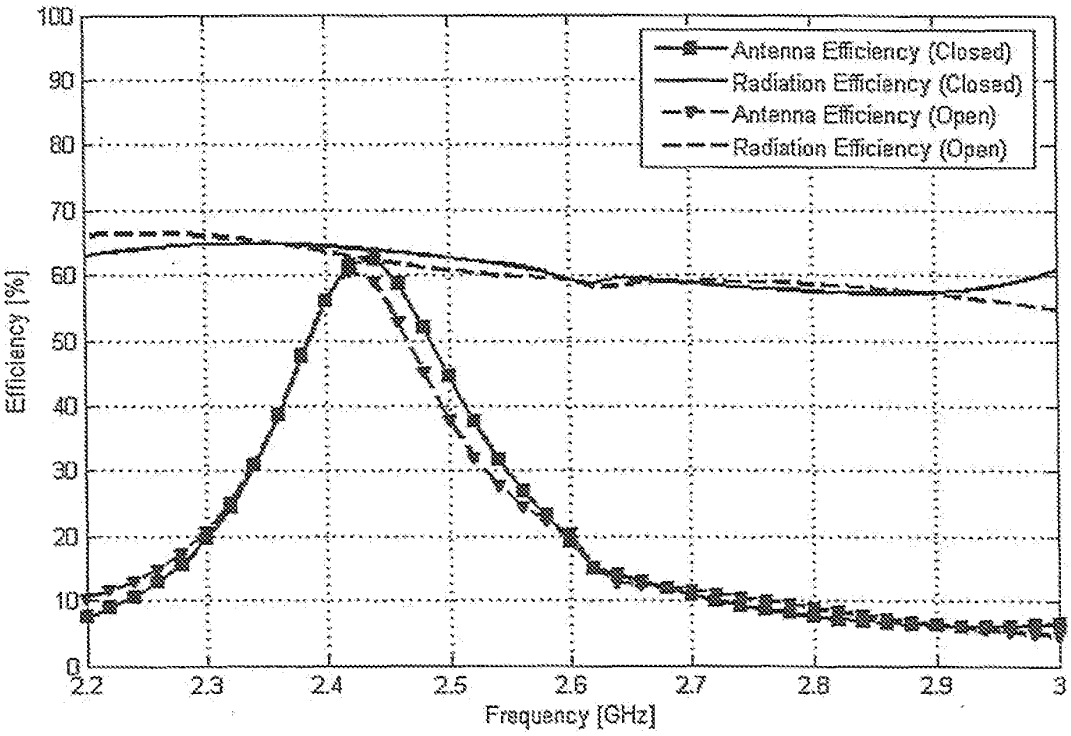

Antenna Efficiency (Closed)
Radiation Efficiency (Closed)
Antenna Efficiency (Open)
Radiation Efficiency (Open)
Efficiency [%]
Frequency [GHz]
100
90
80
70
60
50
40
30
20
10
0
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3

FIG. 6

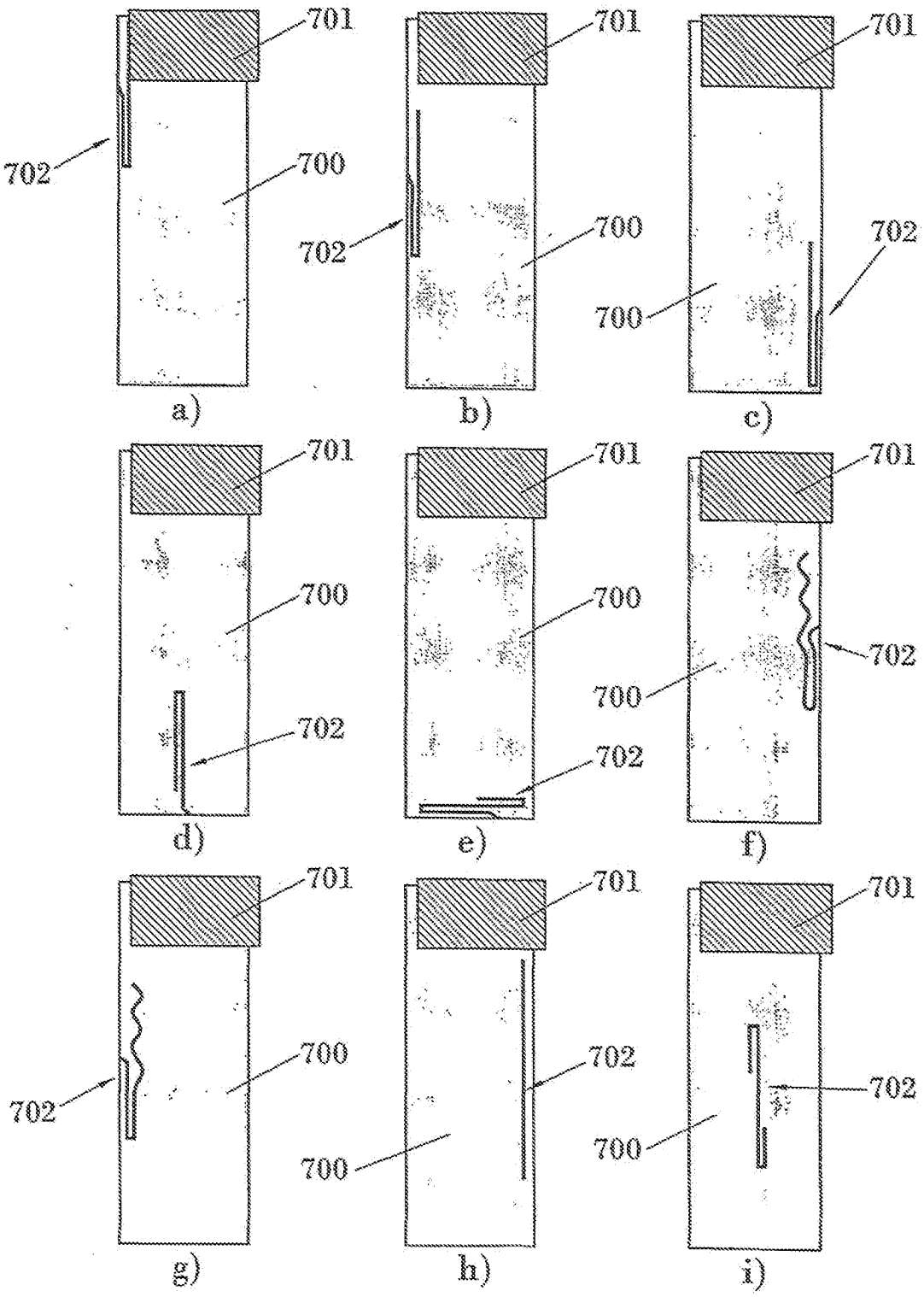
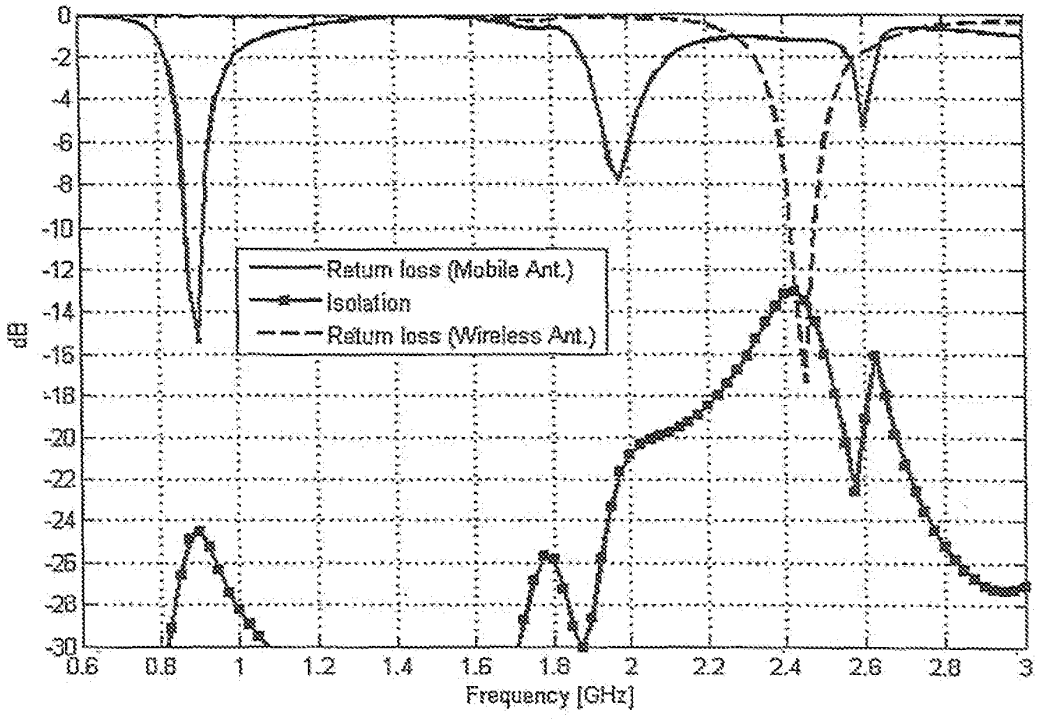
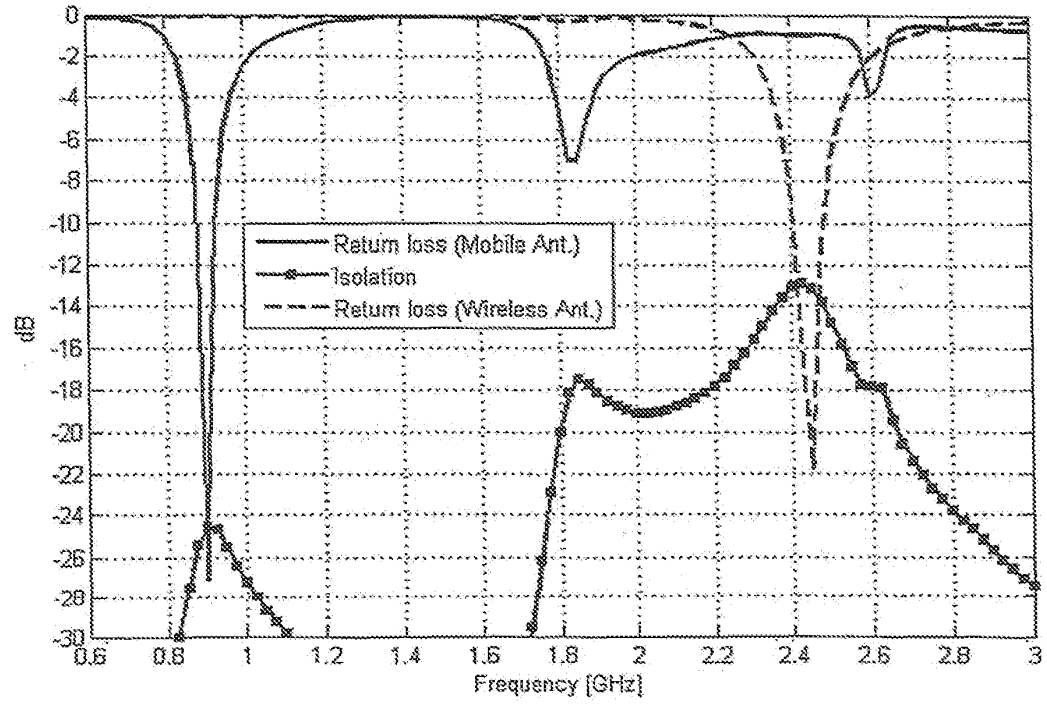


FIG. 7


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

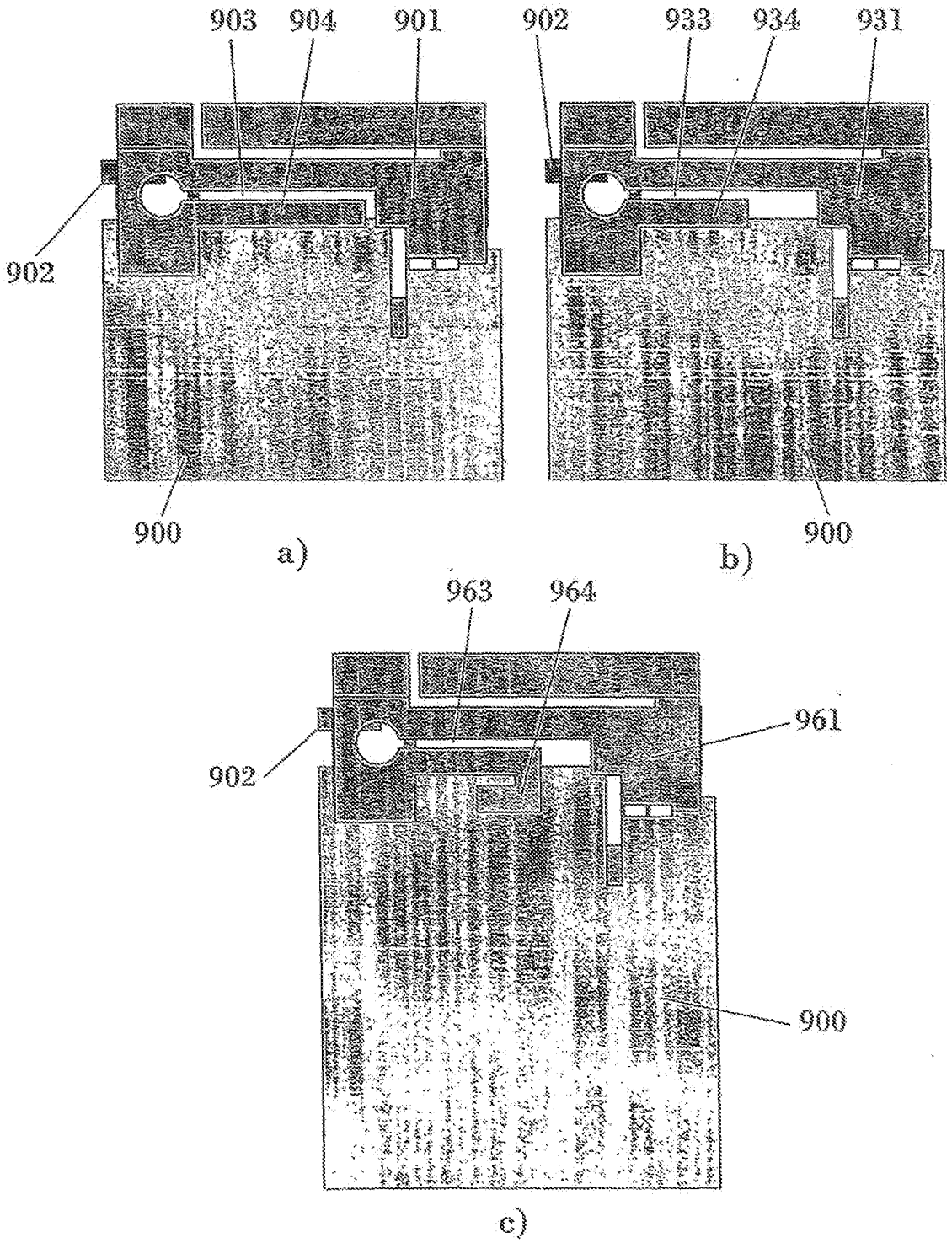


FIG. 9

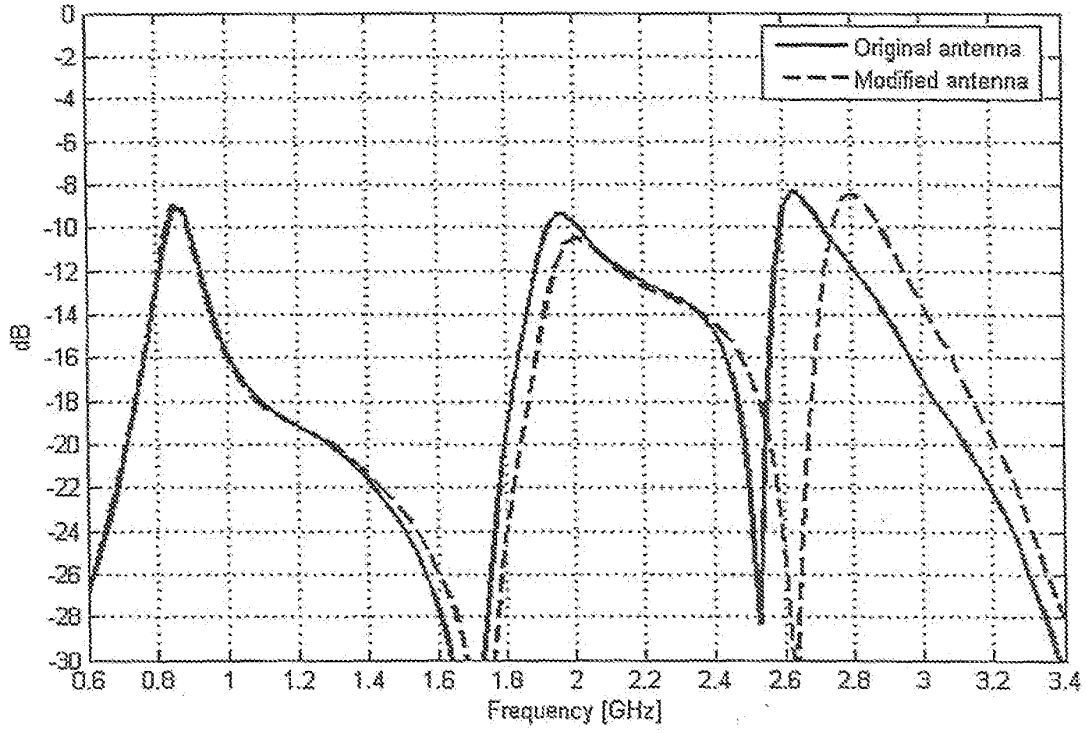
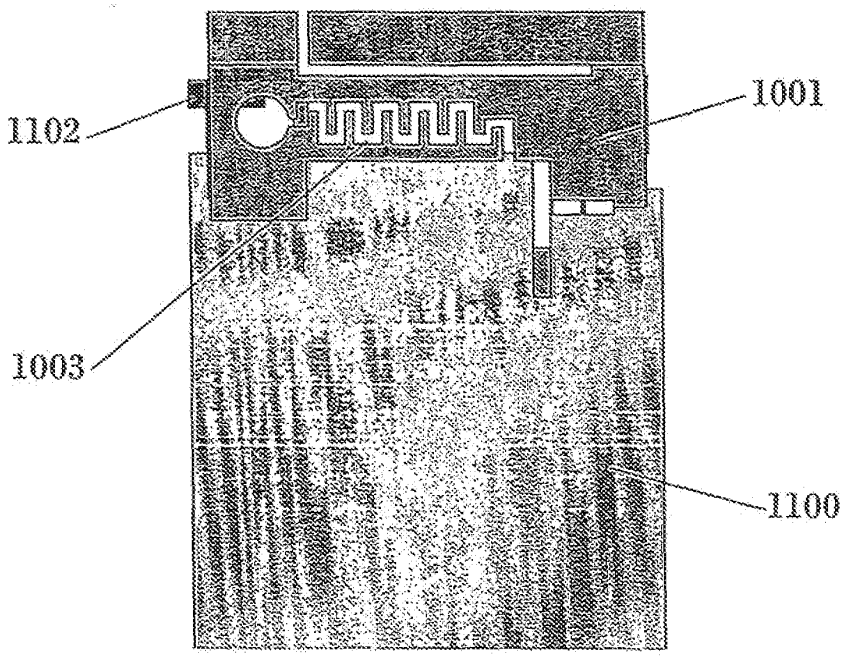
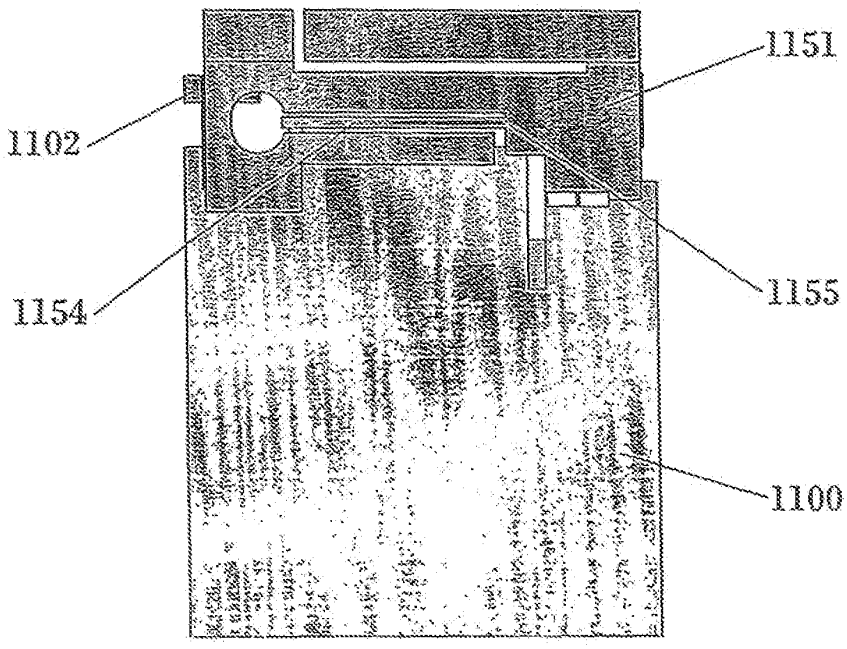

Original antenna
Modified antenna
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 10



a)



b)

FIG. 11

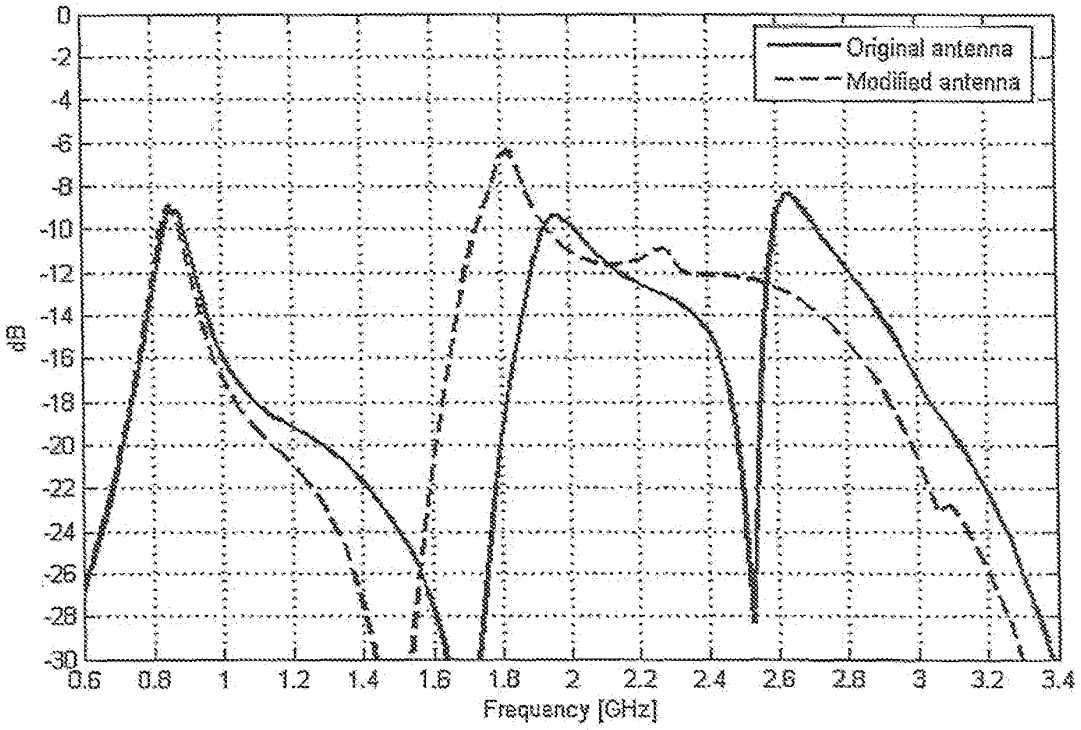
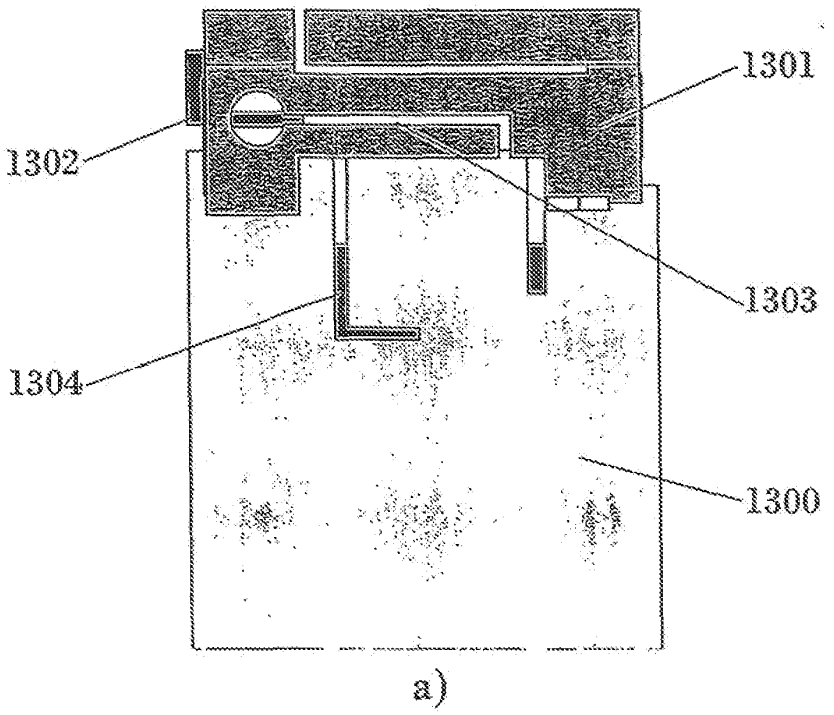
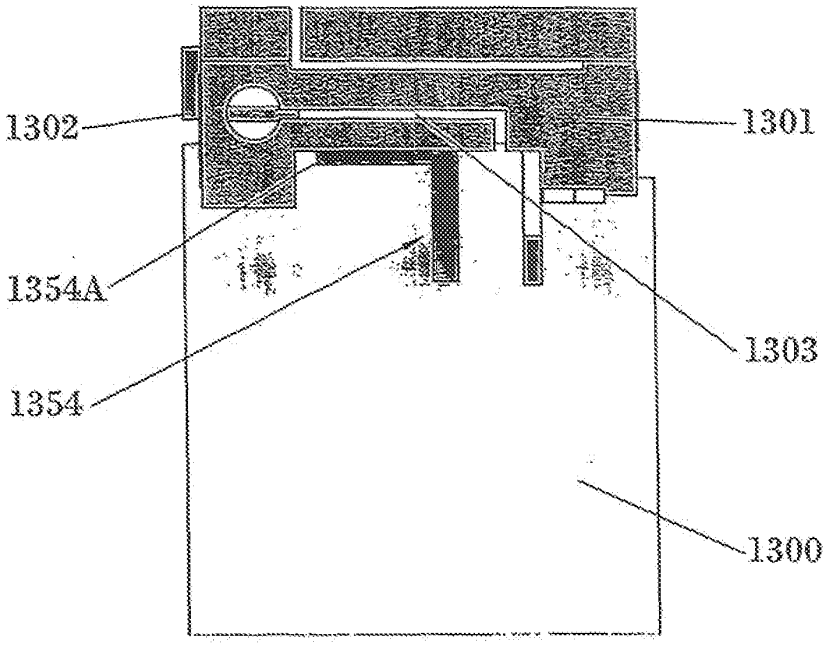

Original antenna
Modified antenna
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 12



a)



b)

FIG. 13

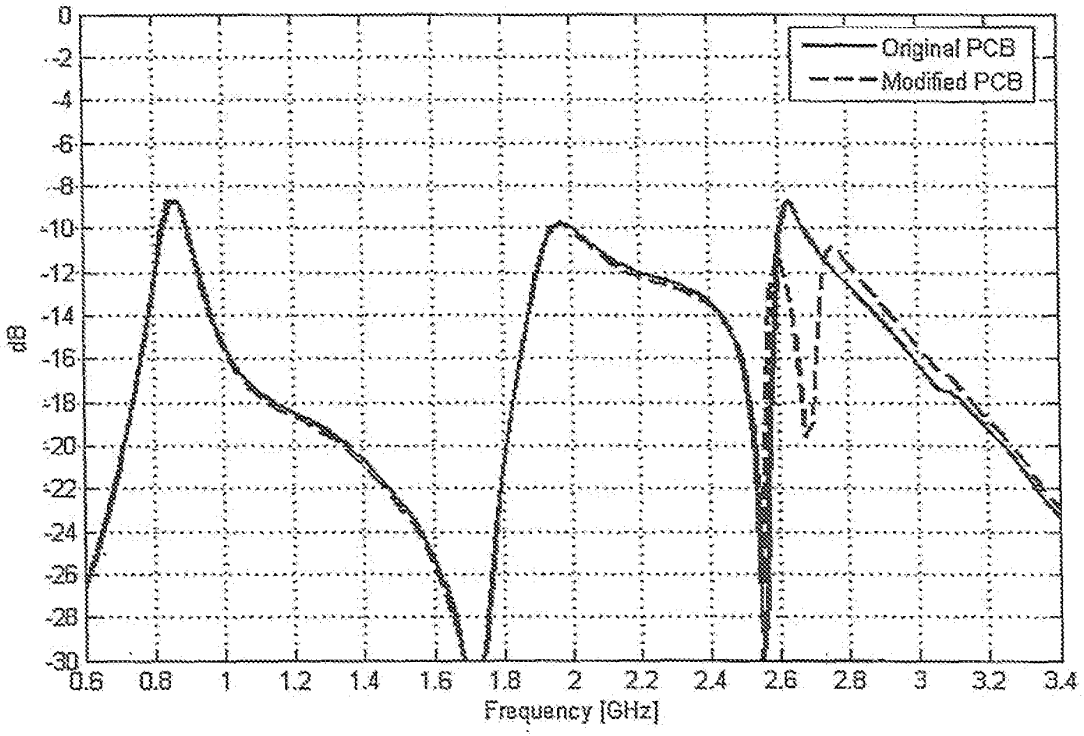
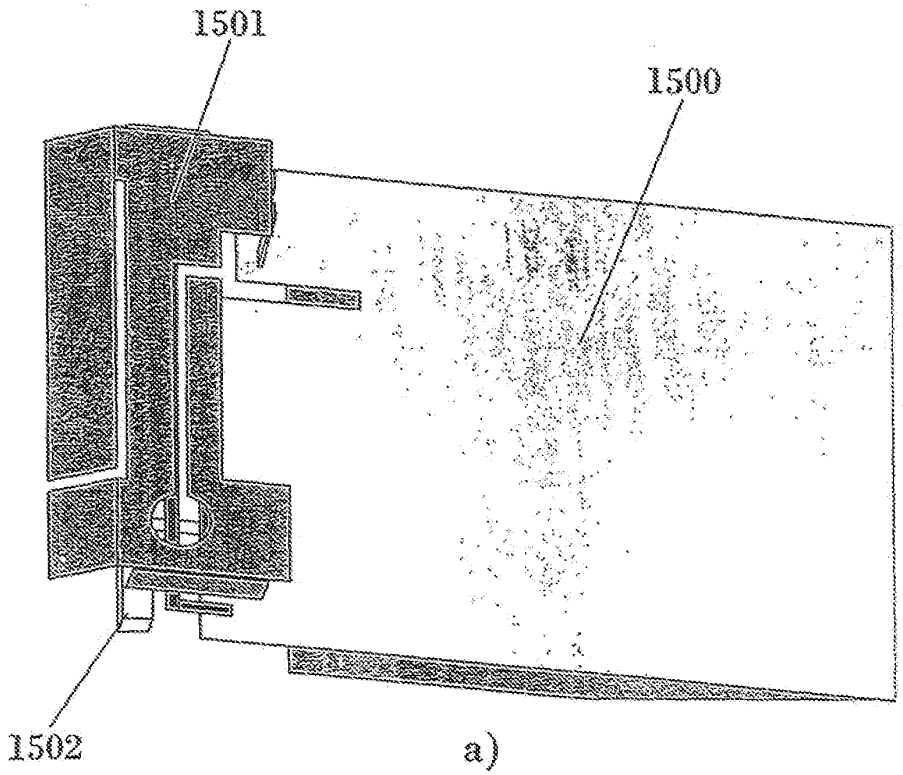
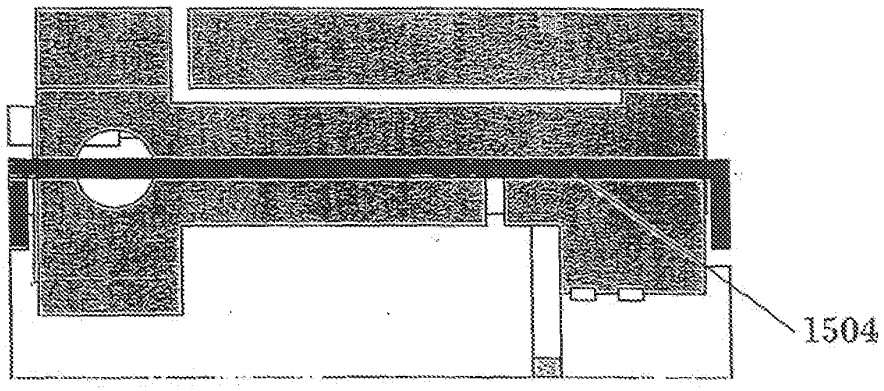

Original PCB
Modified PCB
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 14



a)



b)

FIG. 15

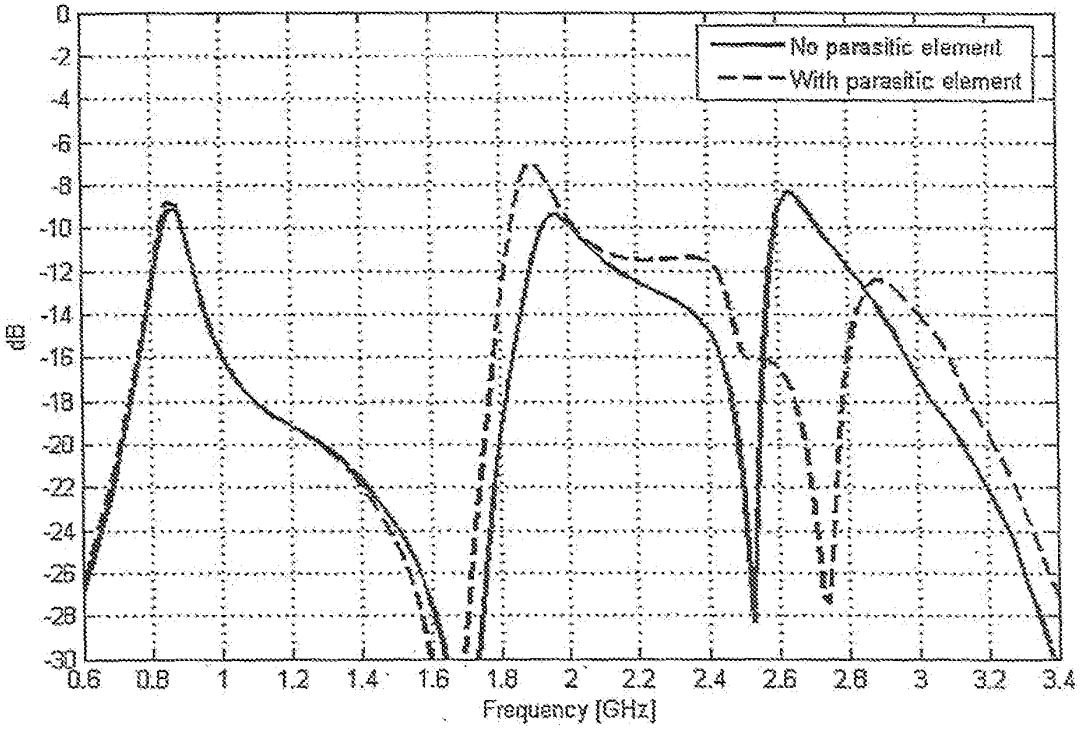

No parasitic element
With parasitic element
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 16

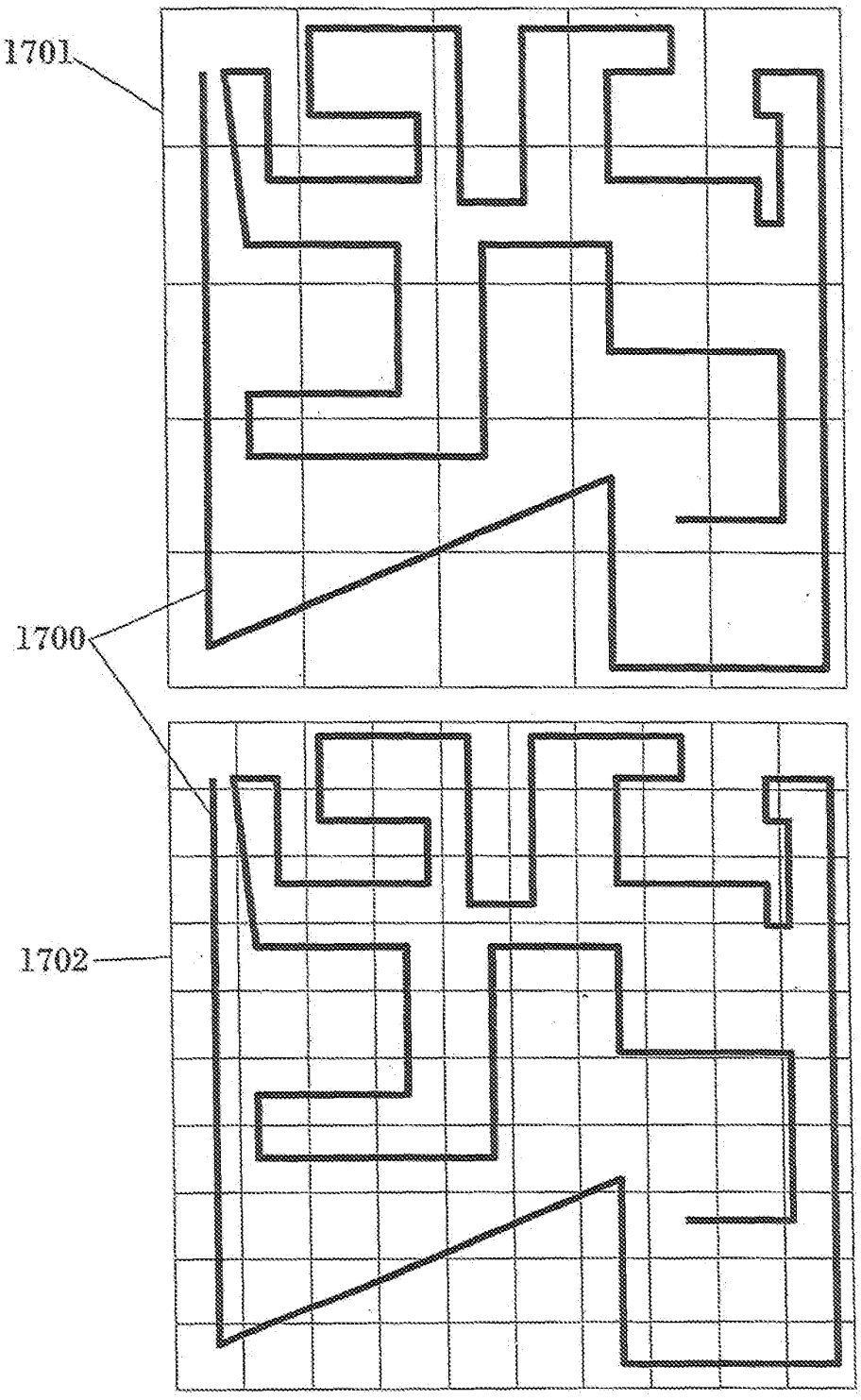


FIG. 17

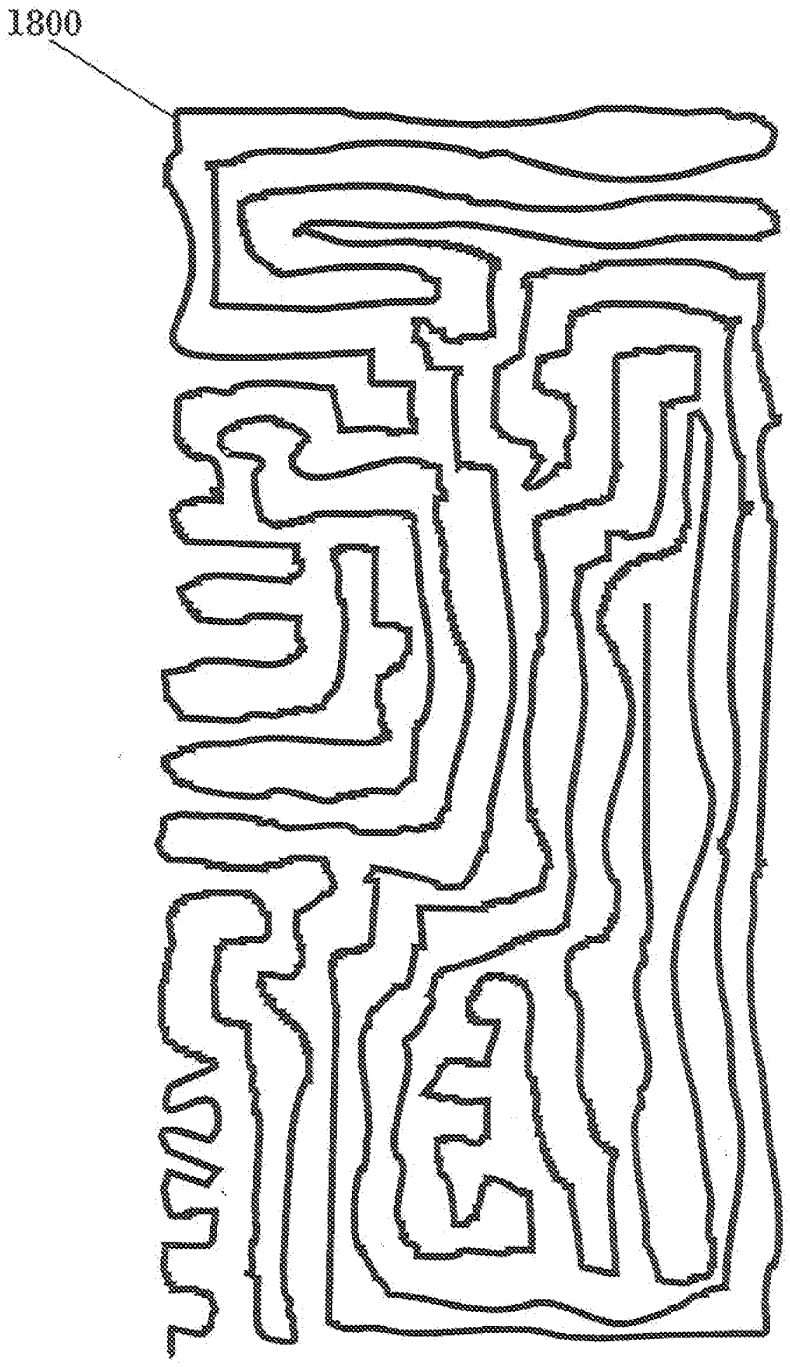


FIG. 18

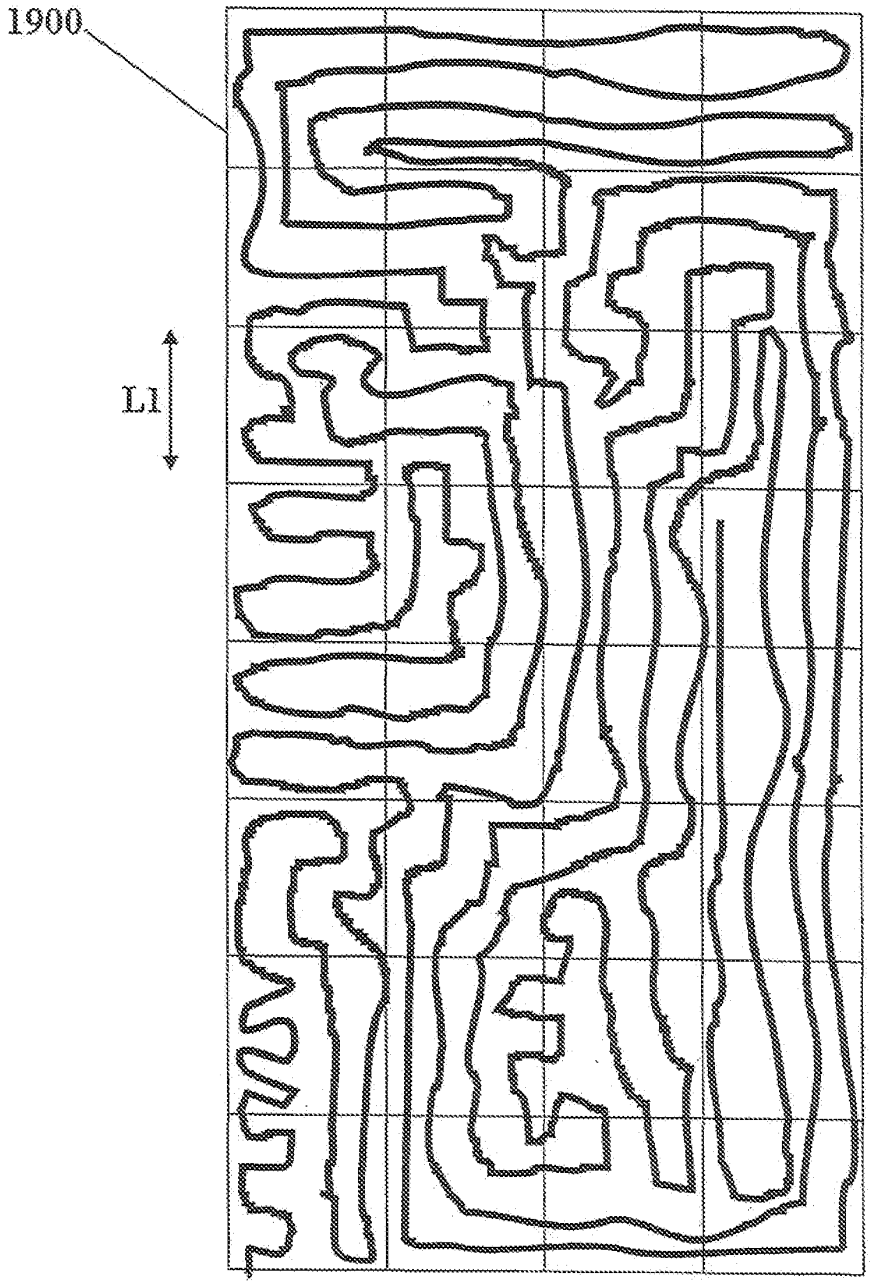


FIG. 19

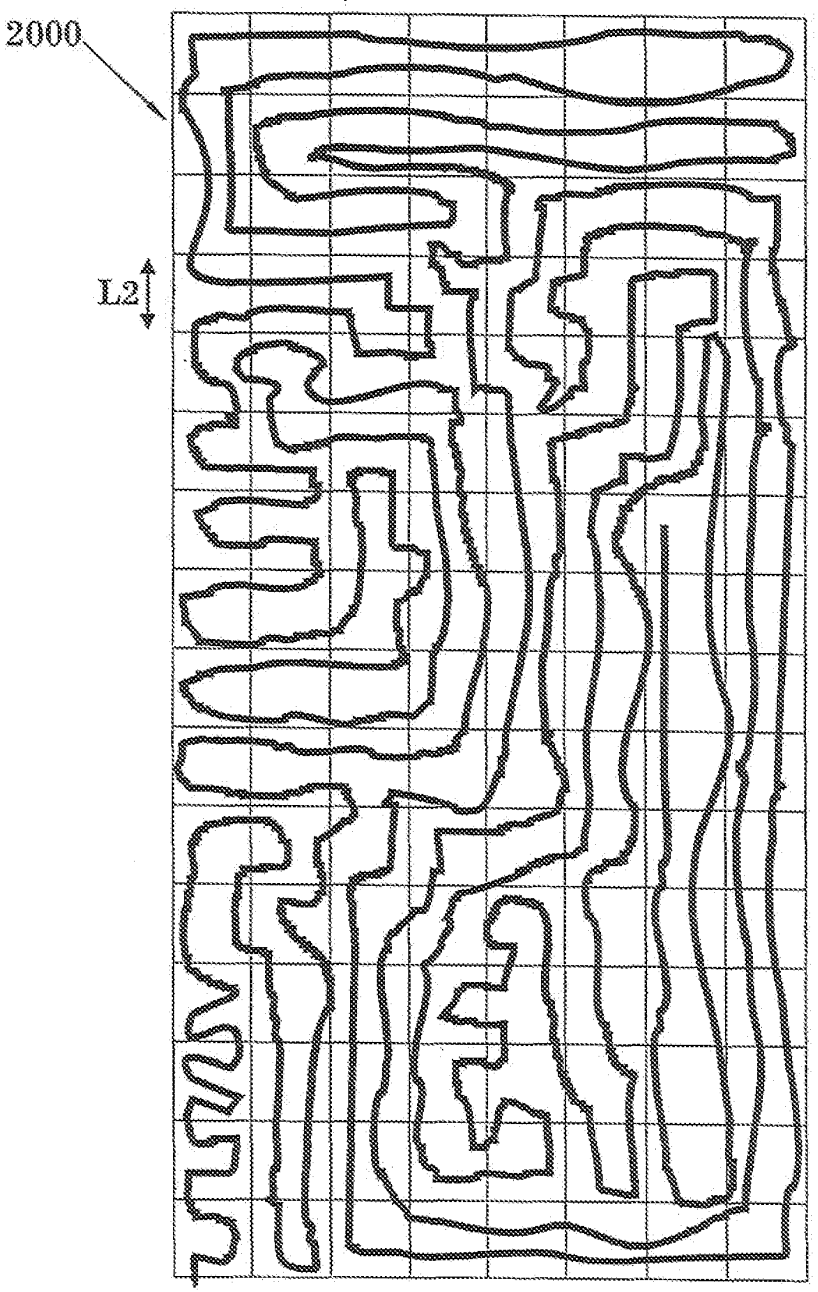


FIG. 20

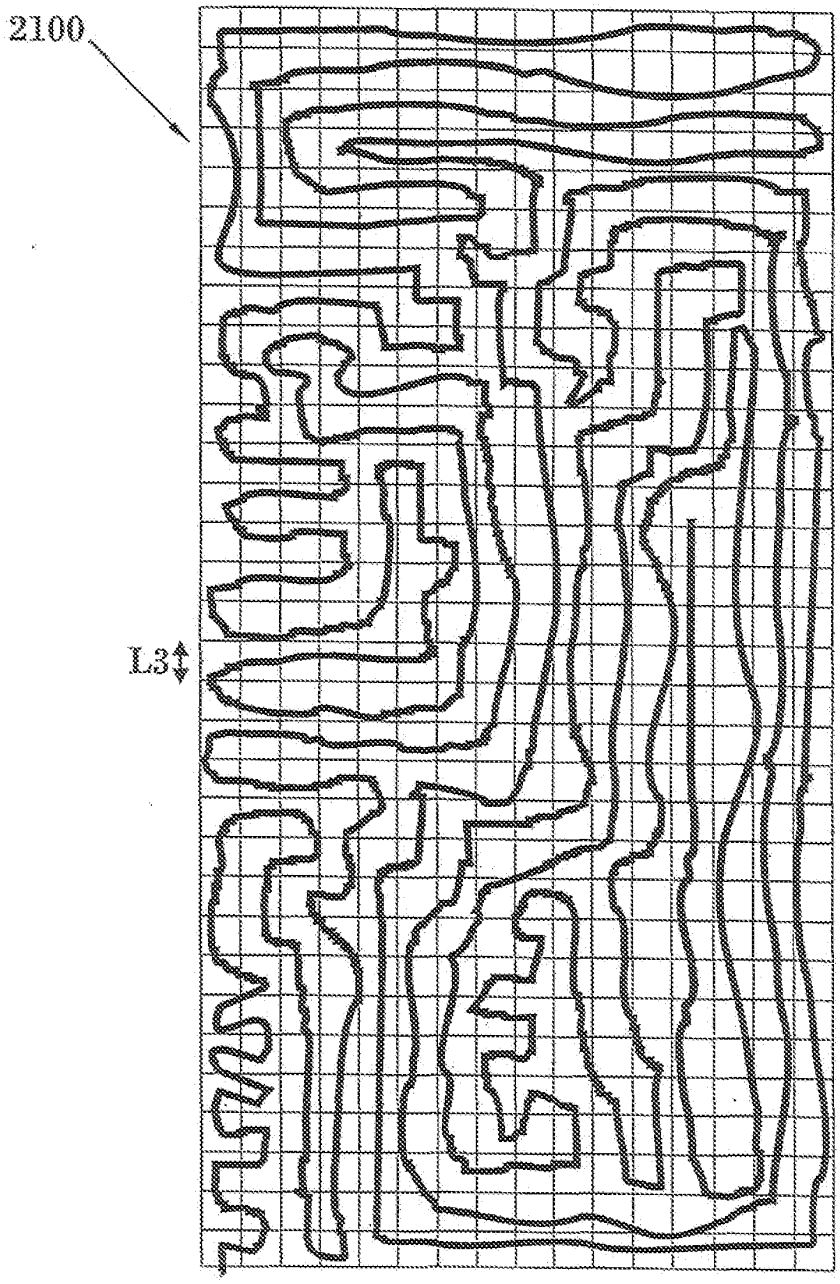


FIG. 21

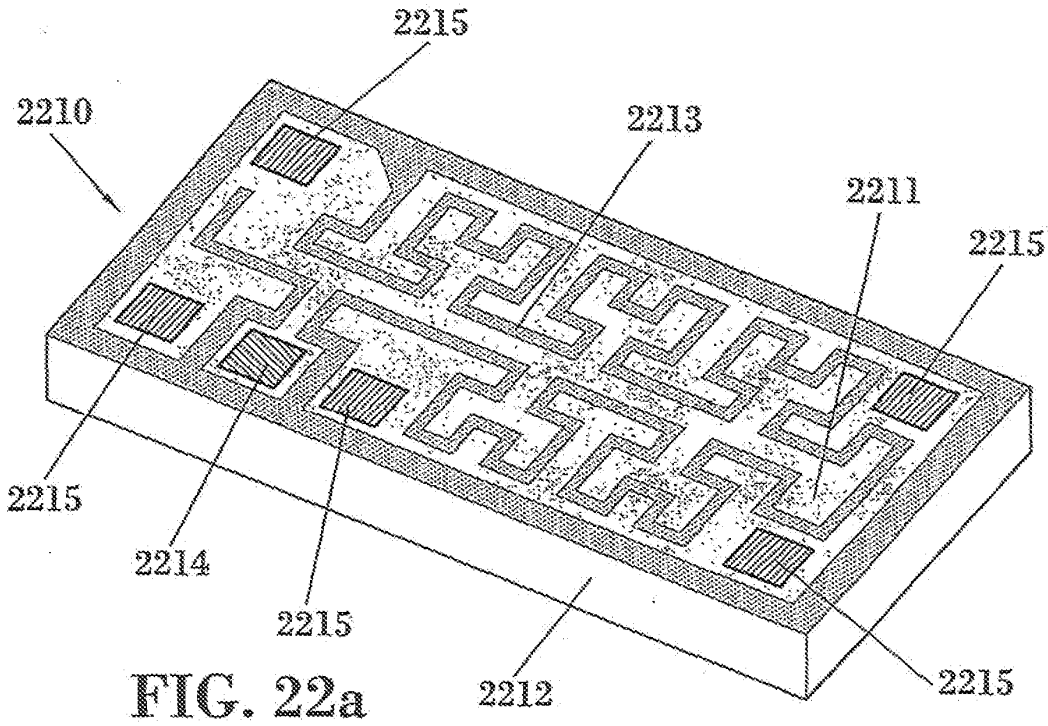


FIG. 22a

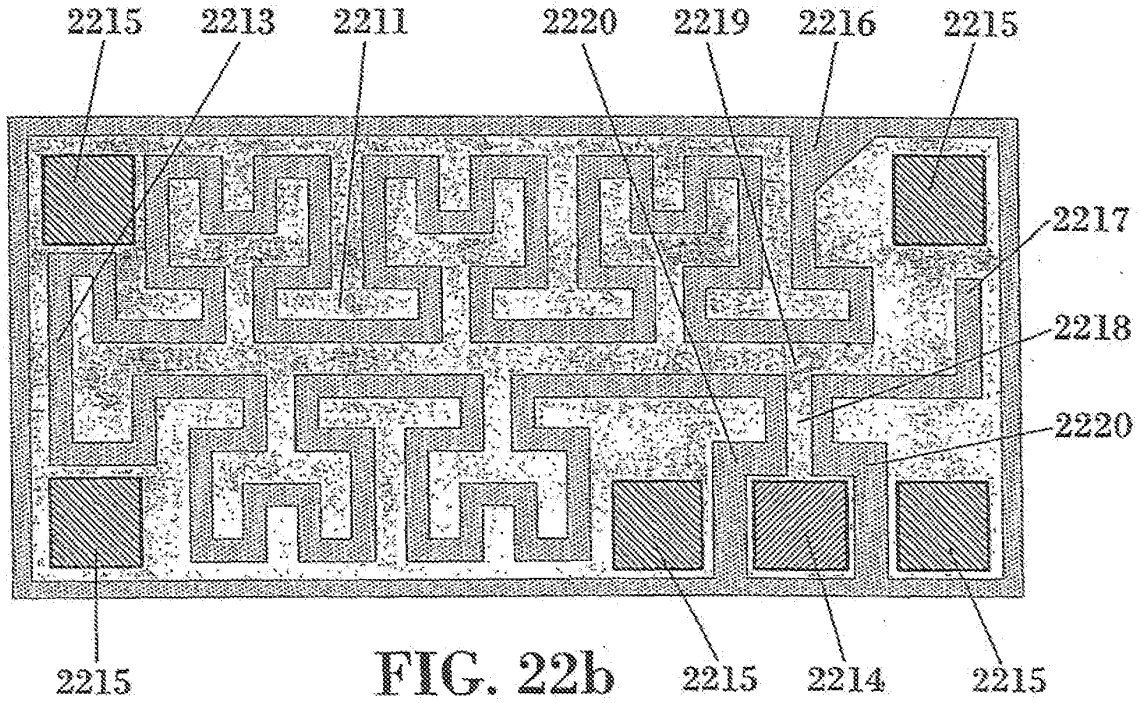


FIG. 22b

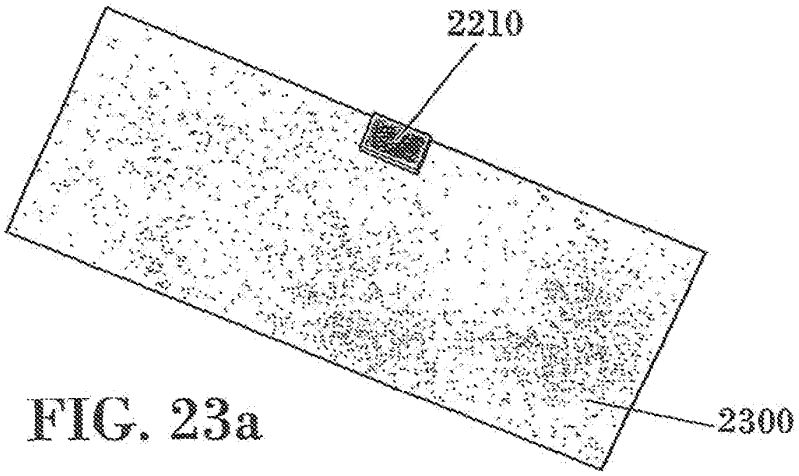


FIG. 23a

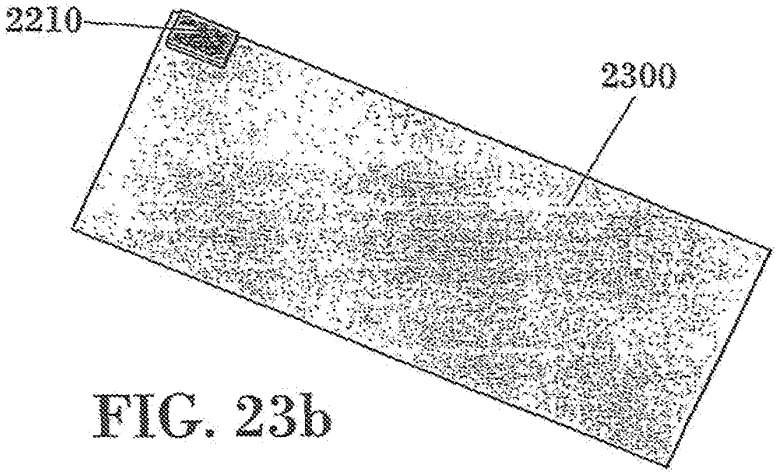


FIG. 23b

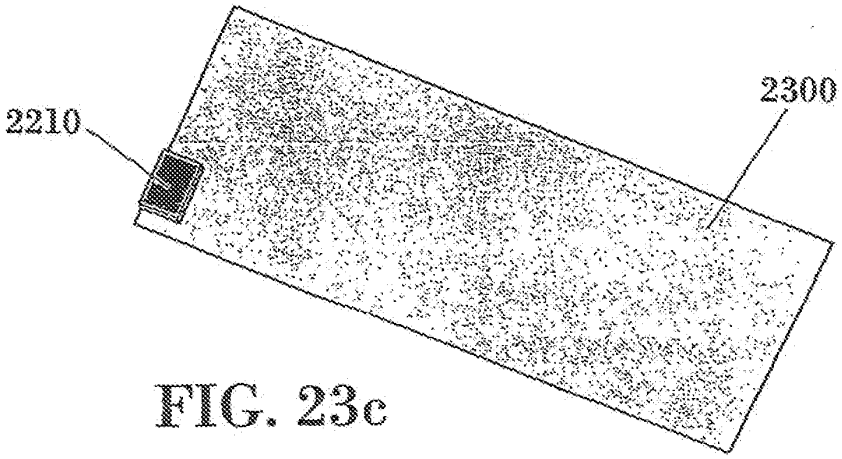


FIG. 23c

SCORE Placeholder Sheet for IFW Content

Application Number: 13718348 Document Date: 12/18/2012

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

- Drawings – Other than Black and White Line Drawings

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

To access the documents in the SCORE database, refer to instructions developed by SIRA.

At the time of document entry (noted above):

- Examiners may access SCORE content via the eDAN interface.
- Other USPTO employees can bookmark the current SCORE URL (http://es/ScoreAccessWeb/).
- External customers may access SCORE content via the Public and Private PAIR interfaces.

Form Revision Date: February 8, 2006

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

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (**Not for submission under 37 CFR 1.99**)		
	Application Number	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

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	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

	9	6624789		2003-09-23	Kangasvieri et al	
	10	6985108		2006-01-10	Mikkola et al	
	11	7170450		2007-01-30	Chang	
	12	7193571		2007-03-20	Inatsugu	

If you wish to add additional U.S. Patent citation information please click the Add button.

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	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

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]
	1	1401050	EP		2004-03-24	Filtronic LK Oy		☐
	2	1445821	EP		2004-08-11	Wistron NeWeb Corp		☐
	3	2005341313	JP		2005-12-08	Matsushita Electric Industrial		☐
	4	01/54225	WO		2001-07-26	Fractus		☐
	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		☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

	11	2006/120250	WO		2006-11-16	Fractus SA		☐

If you wish to add additional Foreign Patent Document citation information please click the Add button

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	Jaggard , D. L. Rebuttal expert report of Dr. Dwight L. Jaggard (redacted version). Fractus. February 16, 2011	☐
	2	Long , S. Rebuttal expert report of Dr. Stuart A. Long (redacted version). Fractus. February 16, 2011	☐
	3	Jaggard , D. L. Expert report of Dwight L. Jaggard (redacted) - expert witness retained by Fractus. Fractus. February 23, 2011	☐
	4	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	☐
	5	Antenna designs for MIMO systems. Antenova. January 1, 2004	☐
	6	Karaboikis , M. et al Compact dual-printed inverted-F antenna diversity systems for portable wireless devices. Antennas and Wireless Propagation Letters, IEEE. January 1, 2004	☐
	7	Latif, S. I. et al. Bandwidth enhancement and size reduction of microstrip slot antennas. Antennas and Propagation, IEEE Transactions on. March 1, 2005	☐
	8	Mavridis , G. A. A planar two-branch diversity antenna for wireless applications. Antennas and Propagation Society International Symposium 2006, IEEE. July 9, 2006	☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

	9	Lindberg , P. et al. Internal active antenna for FM radio reception in mobile handsets. EuCAP. November 8, 2007	☐
	10	PCT/EP2006/007050 - International search report and the written opinion of the International Searching Authority. EPO. December 13, 2006	☐
	11	PCT/EP2006/007050 - Written opinion of the International Searching Authority. EPO. December 13, 2006	☐
	12	US11/988888 - Office action dated on November 24, 2010. USPTO. November 24, 2010	☐
	13	US11/988888 - Amendment and response to restriction requirement. Winstead. December 17, 2010	☐
	14	US11/988888 - Office action dated on October 1, 2011. USPTO. January 10, 2011	☐
	15	US11/988888 - Amendment in response to non-final office action dated on January 10, 2011. Winstead. May 31, 2011	☐
	16	US11/988888 - Notice of allowance dated on July 12, 2011. USPTO. July 12, 2011	☐
	17	US11/988888 - Notice of allowance dated on October 14, 2011. USPTO. October 14, 2011	☐
	18	** US13/341051 - Office action summary dated on February 22, 2012. USPTO. February 22, 2012	☐
	19	** US13/341051 - Response to the office action dated on February 22, 2012. Winstead PC. May 14, 2012	☐

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

	20	** US13/341051 - Office action summary dated on June 21, 2012. USPTO. June 21, 2012	☐
	21	** US13/341051 - Amendment and Response to the final office action dated on June 21, 2012. Winstead. September 14, 2012	☐
	22	** US13/341051 - Notice of allowance dated on September 24, 2012. USPTO. September 24, 2012	☐

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*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.

Electronic Acknowledgement Receipt

EFS ID:	14573910
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	28-DEC-2012
Filing Date:	
Time Stamp:	09:38:34
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		IDS_47005_P040WUSC2_1.PDF	114024 aa92b141730dc712ce0f4c5257b80c3f7c7bc00e	yes	8

	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Transmittal Letter		1	2	
	Information Disclosure Statement (IDS) Form (SB08)		3	8	
Warnings:					
Information:					
2	Non Patent Literature	US13341051_Notice_of_Allowance_Sept_24_2012_2.pdf	1129495 f5285d7832a211c72aa3ab0824203ea493e72013	no	8
Warnings:					
Information:					
3	Non Patent Literature	US13341051_Amendment_and_Response_to_final_office_action_June_21_2012_3.pdf	696229 2086fb5077025b5989ee9054869bf40dd10a1689	no	8
Warnings:					
Information:					
4	Non Patent Literature	US13341051Office_action_summary_June_21_2012_4.pdf	772356 571136d9078c15de013846ec7f551828006c2539	no	7
Warnings:					
Information:					
5	Non Patent Literature	US13341051_Response_to_Office_Action__Feb_22_2012_5.pdf	609359 57c99da28b2007ac43689ee774cca59d6c2f38cf	no	7
Warnings:					
Information:					
6	Non Patent Literature	US13341051_Office_action_Feb_22_2012_6.pdf	382074 2825c22ff0987bbd3510e4ab907a24e4fc74c49d	no	4
Warnings:					
Information:					
		Total Files Size (in bytes):	3703537		

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 37 CFR § 1.6(a)(4).

Dated: December 28, 2012
Electronic Signature for Brenda I. Brown: /Brenda I. Brown/

Docket No.: 47005-P040WUSC2
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Josep Mumbru et al.

Application No.: 13/718,348

Confirmation No.: 8109

Filed: December 18, 2012

Art Unit: N/A

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 Madam:

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)).

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).

The documents with exception to the non-patent literature documents numbers 18-22 cited in the attached form PTO/SB/08 are not supplied because they were previously cited by or submitted to the Office in prior application number 13/341,051 filed December 30, 2011 and relied upon in this application for an earlier filing date under 35 U.S.C. 120. Non-patent literature documents numbers 18-22 are being supplied.

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-P040WUSC2.

Dated: December 28, 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

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/718,348

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	390
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 62 =	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	1260

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($)	ADDITIONAL FEE($)	OR	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

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	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/718,348	12/18/2012	2821	1260	47005-P040WUSC2	20	3

CONFIRMATION NO. 8109

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

FILING RECEIPT

OC000000058759779

Date Mailed: 01/23/2013

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Josep Mumbru, Barcelona, SPAIN;
Jaume Anguera, Castellon, SPAIN;
Jordi Soler, Mataro, SPAIN;
Carles Puente, Sant Cugat del Valles, SPAIN;

Applicant(s)

Fractus, S.A., Sant Cugat del Valles, SPAIN

Assignment For Published Patent Application

Fractus, S.A., Sant Cugat del Valles, SPAIN

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 13/341,051 12/30/2011 PAT 8362960
which is a CON of 11/988,888 09/30/2008 PAT 8115686
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

Request to Retrieve - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to**

Retrieve Electronic Priority Application(s) (PTO/SB/38 or its equivalent). Consequently, the USPTO will attempt to electronically retrieve these priority documents.

If Required, Foreign Filing License Granted: 01/18/2013

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/718,348**

Projected Publication Date: To Be Determined - pending completion of Corrected Papers

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

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

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 U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

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
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2

CONFIRMATION NO. 8109

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

FORMALITIES LETTER

OC000000058759780

Date Mailed: 01/23/2013

NOTICE TO FILE CORRECTED APPLICATION PAPERS

Filing Date Granted

An application number and filing date have been accorded to this application. The application is informal since it does not comply with the regulations for the reason(s) indicated below. Applicant is given TWO MONTHS from the date of this Notice within which to correct the informalities indicated below. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

The required item(s) identified below must be timely submitted to avoid abandonment:

- A substitute specification in compliance with 37 CFR 1.52, 1.121(b)(3), and 1.125, is required. The substitute specification must be submitted with markings and be accompanied by a clean version (without markings) as set forth in 37 CFR 1.125(c) and a statement that the substitute specification contains no new matter (see 37 CFR 1.125(b)). The specification, claims, and/or abstract page(s) submitted is not acceptable and cannot be scanned or properly stored because:
  - The application contains drawings, but the specification does not contain a brief description of the several views of the drawings as required by 37 CFR 1.74 and 37 CFR 1.77(b)(7).
- Replacement drawings in compliance with 37 CFR 1.84 and 37 CFR 1.121(d) are required. The drawings submitted are not acceptable because:
  - The drawings must be reasonably free from erasures and must be free from alterations, overwriting, interlineations, folds, and copy marks. See Figure(s) 7.
  - More than one figure is present and each figure is not labeled "Fig." with a consecutive Arabic numeral (1, 2, etc.) or an Arabic numeral and capital letter in the English alphabet (A, B, etc.)(see 37 CFR 1.84(u)(1)). See Figure(s) 22, 23. A brief description of the several views of the drawings (see 37 CFR 1.74) should be added or amended to correspond to the corrected numbering of the figures. See also 37 CFR 1.77(b)(7).
  - The drawings submitted to the Office are not electronically reproducible because portions of figures 2,4,9,11,13,15 are missing and/or blurry.

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

The applicant needs to satisfy supplemental fees problems indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- A surcharge (for late submission of the basic filing fee, search fee, examination fee or inventor's oath or declaration) as set forth in 37 CFR 1.16(f) of $ **130** for a non-small entity, must be submitted.

SUMMARY OF FEES DUE:

Total fee(s) required within **TWO MONTHS** from the date of this Notice is $ **130** for a non-small entity
- $ **130** Surcharge.

Items Required To Avoid Processing Delays:

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):
  All
  Applicant may submit the inventor's oath or declaration at any time before the Notice of Allowance and Fee(s) Due, PTOL-85, is mailed.

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

/mgabre/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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 December 18, 2012 as Application No. 13/718,348.

The above-identified application was made or authorized to be made by me.

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 131851, Dallas, Texas 75313, to insert above the filing date and/or Application No. of said application.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the above-identified 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 as defined in 37 C.F.R. § 1.56.

I hereby acknowledge that any willful false statement made in this Declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

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:

[X] no such foreign applications have been filed

[ ] such foreign applications 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
			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:

[x] no such U.S. provisional applications have been filed.

[ ] such U.S. provisional applications have been filed as follows:

Application Number	Date of Filing	Priority Claimed Under 35 USC 119

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 as defined in 37 C.F.R. § 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:

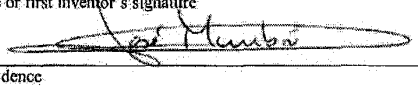
[ ] no such U.S./PCT applications have been filed.

[x] such U.S./PCT applications have been filed as follows:

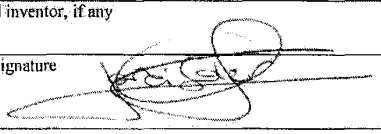
Application Number	Relationship	Parent Application	Date of Filing
This Application	Continuation	13/341,051	December 30, 2011
13/341,051	Continuation	11/988,888	July 18, 2006
11/988,888	National Stage	PCT/EP2006/007050	July 18, 2006
PCT/EP2006/007050	Claims priority	EP 05106694.2	July 21, 2005
PCT/EP2006/007050	35 U.S.C 119(e)	60/702,205	July 25, 2005

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.

Please direct all correspondence to Stanley R. Moore at the address associated with Customer Number 61060.

Full name of sole or first inventor Josep Mumbru	
Sole or first inventor's signature 	Date Jan. 21, 2013
Residence Barcelona, Spain	
Citizenship Spain	
Mailing Address Consell de Cent, 322 08007 Barcelona SPAIN	

Full name of second inventor, if any Jaume Anguera	
Second inventor's signature	Date 7/11/2013
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 29 Jan 2012
Residence Sant Cugat del Valles, Spain	
Citizenship Spain	
Mailing Address Alcalde Barnils, 64-68 Modul C, 3a planta 08174 Sant Cugat del Valles SPAIN	

Full name of fourth inventor, if any Carles Puente	
Fourth inventor's signature	Date 1/17/2013
Residence Sant Cugat del Valles, Spain	
Citizenship Spain	
Mailing Address Alcalde Barnils, 64-68 Modul C, 3a planta 08174 Sant Cugat del Valles SPAIN	

Electronic Patent Application Fee Transmittal

Application Number:	13718348
Filing Date:	18-Dec-2012
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-P040WUSC2

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:				
Late filing fee for oath or declaration	1051	1	130	130
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
			Total in USD ($)	**130**

Electronic Acknowledgement Receipt	
EFS ID:	14858909
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	01-FEB-2013
Filing Date:	18-DEC-2012
Time Stamp:	18:25:21
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$130
RAM confirmation Number	6818
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		Submission_of_Executed_Declaration_1.PDF	149157 c3fd54bbf4204e43a2e5e08af45f082fc3aafe2c	yes	9
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Miscellaneous Incoming Letter		1	2	
	Oath or Declaration filed		3	9	
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30463 f8b83ae36f983c6f9fc4f4fec580d6039eedb4ac	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	179620		

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 deposited with the U.S. Postal Service on the date shown below with sufficient postage as First Class Mail, in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Dated: February 1, 2013
Electronic Signature for Brenda I. Brown: /Brenda I . Brown/

Docket No.: 47005-P040WUSC2
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Josep Mumbru et al.

Application No.: 13/718,348 Confirmation No.: 8109

Filed: December 18, 2012 Art Unit: 2821

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

Examiner: Not Yet Assigned

SUBMISSION OF EXECUTED DECLARATION

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

Dear Madam:

Applicant hereby submits the required executed Declaration.

COMPLETION FEES

Please charge our Deposit Account No. 23-2426 in the amount of $130.00 for payment of the surcharge fee for providing the oath or declaration. The Commissioner is hereby authorized to charge the following additional fees that may be required by this paper and during the pendency of this application or to credit any overpayment in connection herewith to deposit account number 23-2426 of Winstead PC for any of the following fees:

(1)37 CFR §1.16(a) for filing fees;

(2)37 CFR §1.16(b), (c) and (d) for presentation of extra claims;

(3)37 CFR §1.16(e) for payment of the surcharge fee;

(4)37 CFR §1.17(a)(1) (5) for payment of extension fees pursuant to §1.136(a); and

(5)37 CFR §1.17 for payment of application processing fees.

Dated: February 1, 2013

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

PTO/SB/80 (11-08)
Approved for use through 11/30/2011. OMB 0651-0035
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.

POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(b).

I hereby appoint:

[X] Practitioners associated with the Customer Number: 61060

OR

[ ] Practitioner(s) named below (If more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignment documents attached to this form in accordance with 37 CFR 3.73(b).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(b) to:

[ ] The address associated with Customer Number:

OR

[ ] Firm or Individual Name

Address					
City		State		Zip	
Country		Telephone		Email	

Assignee Name and Address:

Fractus, S.A.
C. Alcalde Barnils, 64-68
Edificio Testa - Modulo C, 3°
Parque Empresarial Sant Joan; Sant Cugat del Valles; E-08190 Barcelona; SPAIN

A copy of this form, together with a statement under 37 CFR 3.73(b) (Form PTO/SB/96 or equivalent) is required to be filed in each application in which this form is used. The statement under 37 CFR 3.73(b) may be completed by one of the practitioners appointed in this form if the appointed practitioner is authorized to act on behalf of the assignee, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature		Date	MARCH 5, 2012
Name	RUBEN BOUET	Telephone	+34 935442690
Title	C.E.O.		

5813936v.1 47005/P017WUSC2

Electronic Acknowledgement Receipt

EFS ID:	14859034
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	01-FEB-2013
Filing Date:	18-DEC-2012
Time Stamp:	18:36:09
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	Assignee showing of ownership per 37 CFR 3.73.	Statement_Under_37_CFR_1.PDF	136162 8fa34e10a9125a817d8d89a94c77497da30c6801	no	9

Warnings:

Information:

2	Power of Attorney	Power_of_Attorney_2.PDF	58360 04e75ca85bd5d5b7648c3e472432895c1b28ef7c	no	1

Warnings:	
Information:	
Total Files Size (in bytes):	194522

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/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
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.

STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: Josep Mumbru et al.

Application No./Patent No.: 13/718,348 Filed/Issue Date: December 18, 2012

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

Fractus, S.A. , a Corporation
(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. [x] The assignee of the entire right, title, and interest.

2. [ ] An assignee of less than the entire right, title, and interest (check applicable box):

   [ ] (The extent (by percentage) of its ownership interest is _____ %). Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

   [ ] There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. [ ] The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. [ ] The recipient, via a court proceeding or the like (*e.g.*, bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2, or 3 above (not option 4) is evidence by either (choose **one** of options A or B below):

A. [x] An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____ , Frame _____ , or for which a copy thereof is attached.

B. [ ] A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: _____ To: _____
   The document was recorded in the United States Patent and Trademark Office at Reel _____ , Frame _____ , or for which a copy thereof is attached.

2. From: _____ To: _____
   The document was recorded in the United States Patent and Trademark Office at Reel , Frame , or for which a copy thereof is attached.

PTO/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
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.

STATEMENT UNDER 37 CFR 3.73(c)

3. From: _____ To: _____
The document was recorded in the United States Patent and Trademark Office at
Reel _____ , Frame _____ , or for which a copy thereof is attached.

4. From: _____ To: _____
The document was recorded in the United States Patent and Trademark Office at
Reel _____ , Frame _____ , or for which a copy thereof is attached.

5. From: _____ To: _____
The document was recorded in the United States Patent and Trademark Office at
Reel _____ , Frame _____ , or for which a copy thereof is attached.

6. From: _____ To: _____
The document was recorded in the United States Patent and Trademark Office at
Reel _____ , Frame _____ , or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☒ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Shoaib A. Mithani/	February 1, 2013
Signature	Date
Shoaib A. Mithani	Attorney for Assignee
Printed or Typed Name	Title or Registration Number

ASSIGNMENT

THIS ASSIGNMENT, by Josep Mumbru; Jaume Anguera; Jordi Soler; and Carles Puente (hereinafter Assignors), of Consell de Cent, 322, 08007 Barcelona, SPAIN; Paseo Blasco Ibañez, 15-2, Vinaros, E-12500 Castellon, SPAIN; Alcalde Barnils, 64-68, Modul C, 3a planta, 08174 Sant Cugat del Valles, SPAIN; and Alcalde Barnils, 64-68, Modul C, 3a planta, 08174 Sant Cugat del Valles, SPAIN, respectively;

WHEREAS, Assignors have invented certain new and useful improvements in HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS, set forth in a Patent application for Letters Patent of the United States, already filed on December 18, 2012 as U.S. Application No. 13/718,348; and

WHEREAS, Fractus, S.A., of Alcalde Barnils, 64-68, Modul C, 3rd Floor, 08174 Sant Cugat del Valles, SPAIN (hereinafter referred to as Assignee), is desirous of acquiring the entire right, title and interest in and to the inventions and the Application for Letters Patent of the United States, and in and to any Letters Patent of the United States to be obtained therefor and thereon.

NOW, THEREFORE, in consideration of One Dollar ($1.00) and other good and sufficient consideration, the receipt of which is acknowledged, Assignors have sold, assigned, transferred and set over, and do sell, assign, transfer and set over, unto Assignee, its successors, legal representatives and assigns, the entire right, title and interest in and to the above-mentioned inventions and application for Letters Patent, and in and to any and all direct and indirect divisions, continuations and continuations-in-part of the application, and any and all Letters Patent in the United States and all foreign countries which may be granted therefor and thereon, and reissues, reexaminations and extensions of said Letters Patent, and all rights under the International Convention for the Protection of Industrial Property, same to be held and enjoyed by Assignee, for its own use and benefit and the use and benefit of its successors, legal representatives and assigns, to the full end of the term or terms for which Letters Patent may be granted and/or extended, as fully and entirely as the same would have been held and enjoyed by Assignors, had this sale and assignment not been made.

AND for the same consideration, Assignors represent and warrant to Assignee, its successors, legal representatives and assigns, that, at the time of execution and delivery of these presents, except for any rights, titles and/or interests that have arisen to Assignee under law or that have already been transferred to Assignee, Assignors are the sole and lawful owners of the entire right, title and interest in and to the inventions and application for Letters Patent above-mentioned, and that same are unencumbered and that Assignors have good and full right and lawful authority to sell and convey same in the manner set forth in this Assignment.

AND for the same consideration, Assignors covenant and agree to and with Assignee, its successors, legal representatives and assigns, that Assignors will sign all papers and documents, take all lawful oaths and do all acts necessary or required to be done for the procurement, maintenance, enforcement and defense of any Letters Patent and applications for Letters Patent for said inventions, without charge to Assignee, its successors, legal representatives and assigns, whenever counsel of Assignee, or counsel of its successors, legal representatives and assigns, does advise: that any proceeding in connection with the inventions, or Patent application for Letters Patent, or any proceeding in connection with any Letters Patent or applications for Letters Patent for the inventions in any country, including but not limited to interference proceedings, is lawful and desirable; or, that any division, continuation or continuation-in-part of any application for Letters Patent, or any reissue, reexamination or extension of any Letters Patent, to be obtained thereon, is lawful and desirable.

AND Assignors request the Commissioner of Patent and Trademarks to issue Letters Patent of the United States to Assignee, as Assignee of inventions and the Letters Patent to be issued thereon, for the sole use and benefit of Assignee, its successors, legal representatives and assigns.

AND Assignors hereby grant the following individuals the power to insert on this Assignment any further identification that may be necessary or desirable in order to comply with the rules of the United States Patent and Trademark Office for recordation of this document:

WINSTEAD PC

All practitioners at Customer Number 61060

AND Assignors acknowledge an obligation of assignment of this invention to Assignee at the time the invention was made.

Jan. 21, 2013
Date

Josep Mumbru

Witness:

January 21, 2013
Date

Inma Carrera

17/11/2013
Date

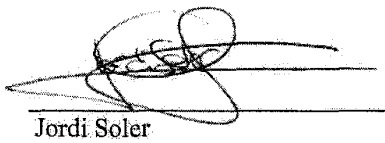
Jaume Anguera

Witness:

January 17, 2013
Date

IMMA CARRERA

29 Jan 2013
Date



Jordi Soler

Witness:

January 29, 2013
Date

Inma Carrera

1/17/2013
Date

Carles Puente

Witness:

January 17, 2013
Date

INMA CARRERA

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: April 22, 2013
Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

Docket No.: 47005-P040WUSC2
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Joseph Mumbru et al.

Application No.: 13/718,348 Confirmation No.: 8109

Filed: December 18, 2012 Art Unit: 2821

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

Examiner: Not Yet Assigned

RESPONSE TO NOTICE TO FILE CORRECTED APPLICATION PAPERS

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

Dear Madam:

In response to the Notice to File Corrected Application Papers – Filing Date Granted mailed January 23, 2013, Applicant respectfully submits a Substitute Specification (marked up and clean versions), Drawing(s) (45 figures, 23 pages), and a Petition for Extension of Time.

Applicant submitted the executed declaration on February 1, 2013 and paid the required fee amount of $130.00.

Pleasae charge Deposit Account No. 23-2426 in the amount of $200.00 for the one month extension of time. 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-P040WUSC2.

Dated: April 22, 2013

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 Patent Application Fee Transmittal

Application Number:	13718348
Filing Date:	18-Dec-2012
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-P040WUSC2

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:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 1 month with $0 paid	1251	1	200	200

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
			Total in USD ($)	**200**

Electronic Acknowledgement Receipt	
EFS ID:	15574709
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	22-APR-2013
Filing Date:	18-DEC-2012
Time Stamp:	12:37:26
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$200
RAM confirmation Number	11057
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 1.19 (Document supply fees) Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)	

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	Specification	6036105_1-CleanVersion_1.PDF	231081 a26781de1e1f868e916e4d24ef682d85dd47ed77	no	46
Warnings:					
Information:					
2	Specification	6036109_1-MarkedUp_2.PDF	237683 d3c45c084b563f1abd03885b5c8c32d457b3f1f4	no	46
Warnings:					
Information:					
3	Drawings-only black and white line drawings	6037515_1-Drawings_3.PDF	4229688 c88111ca93558f6431ad8656f5e5b2c76d2e9bf7	no	23
Warnings:					
Information:					
4	Extension of Time	6037264_1-ExtensionOfTime_4.PDF	22169 89257d7dc88de84708611058827a6c3a3c81c997	no	1
Warnings:					
Information:					
5	Miscellaneous Incoming Letter	6037265_1-Response_5.PDF	20091 7165b28ad4148fa8165ed51b1aa7f3c4875702f9	no	2
Warnings:					
Information:					
6	Fee Worksheet (SB06)	fee-info.pdf	30538 edfac864b4bdb82b4bf5b788f08af76a20e2d24d	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	4771250		

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.

CLEAN VERSION OF SUBSTITUTE SPECIFICATION

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 Figs. 1(A-B)). 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 Fig. 2. For this example, the handset has been selected to have a slider-type topology as schematically illustrated in Figs. 1(A-B). 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 Fig. 1A or in an open position, as shown in Fig. 1B. 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 Figs. 1(A-B)). 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 Fig. 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 Fig. 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 Fig. 2 are shown without any limiting purpose in Figs. 3(A-B). Fig. 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 Fig. 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.

Figs. 17(A-B) 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.

Fig. 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 Fig. 18 enclosed in a first grid 1900 having thirty-two (32) square cells, each with a length L1. Fig. 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 Fig. 19 and Fig. 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 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:

Figs. 1(A-B) – 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): **(Fig. 1A)** General view of the PCBs of the handset in the closed position; and **(Fig. 1B)** 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.

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

Figs. 4(A-B) – 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: **(Fig. 4A)** General view of the PCB of the handset carrying the two antennas; and **(Fig. 4B)** detailed view of the region that contains the slot antenna.

Figs. (A-B) – Typical electrical performance of the antennas of the handset shown in Figs. (A-B): **(Fig. 5A)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and **(Fig. 5B)** 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 (A-I) – 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.

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

Figs. 9(A-C) 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 **(Fig. 9B)** modifying the dimensions of an arm of the mobile antenna; or **(Fig. 9C)** 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.

Figs. 11(A-B) – 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: **(Fig. 11A)** shaping the slot as a meander-like curve; or **(Fig. 11B)** 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.

Figs. 13(A-B) – 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: **(Fig. 13A)** introducing a slot on the PCB; or **(Fig. 13B)** 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.

Figs. 15(A-B) – 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: **(Fig. 15A)** General view of the PCB of the handset; and **(Fig. 15B)** 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 Figs. 15(A-B), in the handset.

Figs. 17(A-B) – Example of a box counting curve located in a first grid **(Fig. 17A)** of 5x5 boxes and in a second grid **(Fig. 17B)** 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.

Figs. 22(A-B) – Example of a slot antenna component.

Figs. 23(A-C) – 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 Figs. 4(A-B)). In the example of Figs. 4(A-B), 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 Figs. 4(A-B)). 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 Figs. 4(A-B), 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 Figs. 7(A-I)). 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.

Figs. 5(A-B) presents, without any limiting purpose, an example of electrical results for the handset of Figs. 4(A-B) according to the present invention. Fig. 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 Fig. 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 Figs. 4(A-B) is better than the results obtained for the example of a conventional prior-art arrangement in Fig. 2. A typical radiation performance of the slot antenna (402) is shown without any limiting purpose in Fig. 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.

Figs. 7(A-I) present, 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 Fig. 7C is expected to be better than for the case of Fig. 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 Fig. 7B is presented without any limiting purpose in Figs. 8(A-B). As it can be observed, the return loss of each antenna is practically the same as the one already presented in Figs. 5(A-B). 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 Fig. 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 Fig. 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 Fig. 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 Fig. 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 Fig. 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). Fig. 10 presents without any

limiting purpose a typical antenna isolation that can be obtained with a modified mobile antenna like the one in Fig. 9C, and compares it with the isolation obtained with the original mobile antenna (Fig. 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. Figs. 11(A-B) 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 Fig. 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 Fig. 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). Fig. 12 presents without any limiting purpose a typical antenna isolation that can be obtained with a modified mobile antenna like the one in Fig. 11B, and compares it with the isolation obtained with the original mobile antenna (Fig. 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.

Fig. 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 Fig. 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.

Fig. 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 Fig. 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).

Fig. 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 Fig. 13B. Compared with the isolation curve obtained in the original handset (Fig. 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 Fig. 13A, or two or more conducting strips shorted to the ground plane of the PCB, like the conducting stripe (1354) in Fig. 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 Fig. 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 Fig. 15(A-B), 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 Fig. 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 Figs. 13(A-B) and 15(A-B)) 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.

Figs. (A-B) 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 Figs. 22(A-B), 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 Figs. 22(A-B), 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 90º), however said connection could also occur at angles smaller or larger than 90º.

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.

Figs. 22(A-B) 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 Figs. 22(A-B), 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 Figs. 23(A-B) 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 Figs. 23(A-C), 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.

MARKED UP VERSION OF SUBSTITUTE SPECIFICATION

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~~ Figs. 1(A-B)). 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~~ Fig. 2. For this example, the handset has been selected to have a slider-type topology as schematically illustrated in ~~Figure 1~~ Figs. 1(A-B). 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 1a~~ Fig. 1A or in an open position, as shown in ~~Figure 1b~~ Fig. 1B. 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~~ Figs. 1(A-B)). 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~~ Fig. 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~~ Fig. 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~~ Fig. 2 are shown without any limiting purpose in ~~Figure 3~~ Figs. 3(A-B). ~~Figure 3a~~ Fig. 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~~ Fig. 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~~ Figs. 17(A-B) 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~~ Fig. 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~~ Fig. 18 enclosed in a first grid 1900 having thirty-two (32) square cells, each with a length L1. ~~Figure~~ Fig. 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~~ Fig. 19 and ~~Figure~~ Fig. 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~~ 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~~ 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**~~ **Figs. 1(A-B)** – 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)**~~ **(Fig. 1A)** General view of the PCBs of the handset in the closed position; and ~~**(b)**~~ **(Fig. 1B)** 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**~~ **Figs. 3(A-B)** – Typical electrical performance of the antennas of the handset shown in ~~**(a)**~~ **Fig. 3A:** Return loss of each antenna and isolation between antennas when the handset is in closed position; and ~~**(b)**~~ **(Fig. 3B)** return loss of each antenna and isolation between antennas when the handset is in open position.

~~**Fig. 4**~~ **Figs. 4(A-B)** – 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)**~~ **(Fig. 4A)** General view of the PCB of the

handset carrying the two antennas; and ~~(b)~~ **(Fig. 4B)** detailed view of the region that contains the slot antenna.

~~**Fig. 5**~~ **Figs. (A-B)** – Typical electrical performance of the antennas of the handset shown in ~~Fig. 4~~ Figs. (A-B): ~~**(a)**~~ **(Fig. 5A)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and ~~**(b)**~~ **(Fig. 5B)** 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 (A-I) – 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**~~ **Figs. 8(A-B)** – Typical electrical performance of the antennas of the handset shown in ~~Figure 7b~~ Fig. 7B: ~~**(a)**~~ **(Fig. 8A)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and ~~**(b)**~~ **(Fig. 8B)** return loss of each antenna and isolation between antennas when the handset is in open position.

~~**Fig. 9 – (a)**~~ **Figs. 9(A-C)** 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)**~~ **(Fig. 9B)** modifying the dimensions of an arm of the mobile antenna; or ~~**(c)**~~ **(Fig. 9C)** 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~~ 9B.

~~Fig. 11~~ Figs. 11(A-B) – 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)~~ (Fig. 11A)** shaping the slot as a meander-like curve; or **~~(b)~~ (Fig. 11B)** 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~~ 11B.

~~Fig. 13~~ Figs. 13(A-B) – 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)~~ (Fig. 13A)** introducing a slot on the PCB; or **~~(b)~~ (Fig. 13B)** 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~~ 13B.

~~Fig. 15~~ Figs. 15(A-B) – 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)~~ (Fig. 15A)** General view of the PCB of the handset; and **~~(b)~~ (Fig. 15B)** 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~~ 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~~ Figs. 15(A-B), in the handset.

~~**Fig. 17**~~ **Figs. 17(A-B) –** Example of a box counting curve located in a first grid **(Fig. 17A)** of 5x5 boxes and in a second grid **(Fig. 17B)** 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**~~ **Figs. 22(A-B)** – Example of a slot antenna component.

~~**Fig. 23**~~ **Figs. 23(A-C)** – 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~~ Figs. 4(A-B)). In the example of ~~Figure 4~~ Figs. 4(A-B), 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~~ Figs. 4(A-B)). 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~~ Figs. 4(A-B), 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~~

Figs. 7(A-I)). 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.

~~Fig. 5~~ Figs. 5(A-B) presents, without any limiting purpose, an example of electrical results for the handset of ~~Fig. 4~~ Figs. 4(A-B) according to the present invention. ~~Figure 5a~~ Fig. 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~~ Fig. 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~~ Figs. 4(A-B) is better than the results obtained for the example of a conventional prior-art arrangement in ~~Figure~~ Fig. 2. A typical radiation performance of the slot antenna (402) is shown without any limiting purpose in ~~Figure~~ Fig. 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~~ Figs. 7(A-I) present, 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~~ Fig. 7C is expected to be better than for the case of ~~Figure 7a~~ Fig. 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~~ Fig. 7B is presented without any limiting purpose in ~~Figure 8~~ Figs. 8(A-B). As it can be observed, the return loss of each antenna is practically the same as the one already presented in ~~Figure 5~~ Figs. 5(A-B). 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 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 ~~Figure 9a~~ Fig. 9A, where the tip of arm (904) defined the open end of the slot (903). ~~Figure~~ Fig. 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~~ Fig. 9C, and compares it with the isolation obtained with the original mobile antenna ~~Figure 9a~~ (Fig. 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~~ Figs. 11(A-B) 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 11B, and compares it with the isolation obtained with the original mobile antenna ~~Figure 9a~~ (Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 13B. Compared with the isolation curve obtained in the original handset ~~Figure 9a~~ (Fig. 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~~ Fig. 13A, or two or more conducting strips shorted to the ground plane of the PCB, like the conducting stripe (1354) in ~~Figure 13b~~ Fig. 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~~ Fig. 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~~ Fig. 15(A-B), 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~~ Fig. 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 ~~Figures13 and 15~~ Figs. 13(A-B) and 15(A-B)) 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~~ Figs. (A-B) 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~~ 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~~ 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~~ Figs. 22(A-B), 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 ~~Fig. 22~~ Figs. 22(A-B), 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 90º), however said connection could also occur at angles smaller or larger than 90º.

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.

~~Fig. 22~~ Figs. 22(A-B) 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~~ Figs. 22(A-B), 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~~ Figs. 23(A-B) 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~~ 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~~ 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~~ 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~~ Figs. 23(A-C), 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.

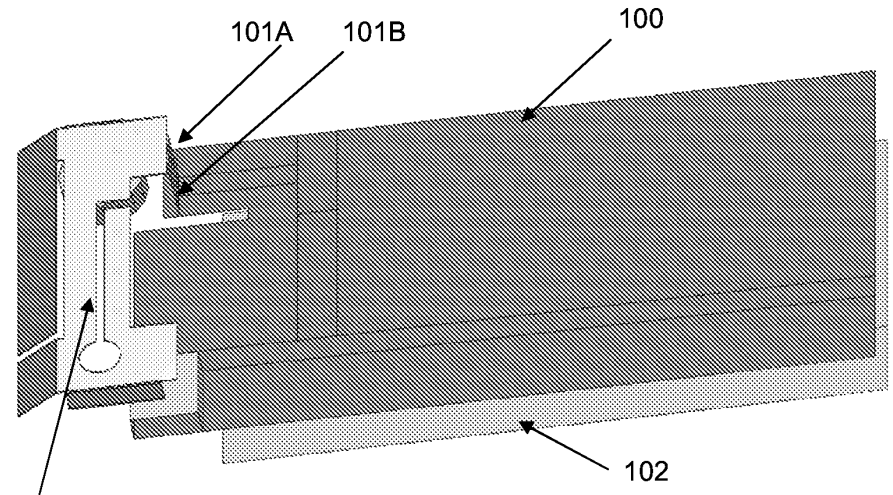


FIG. 1A

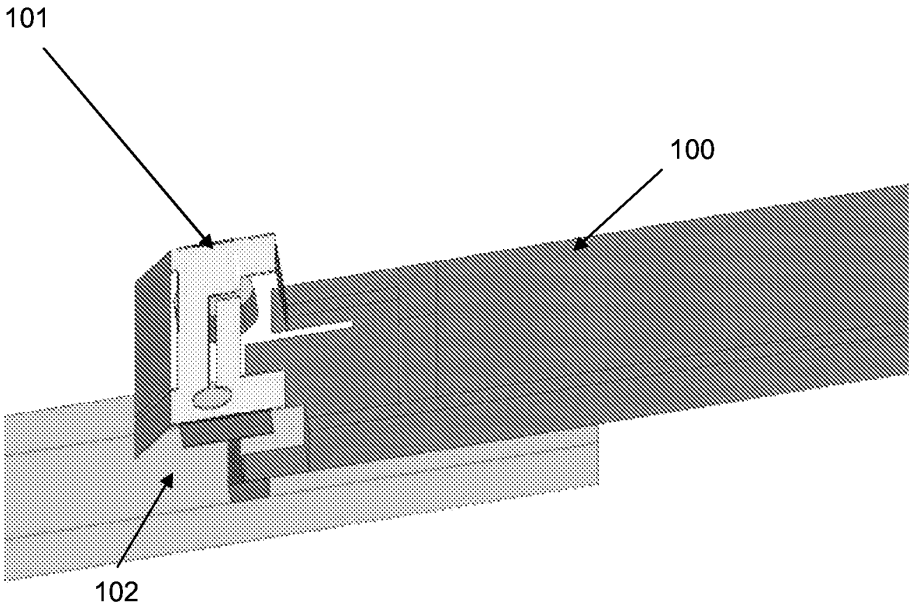


FIG. 1B

(PRIOR ART)

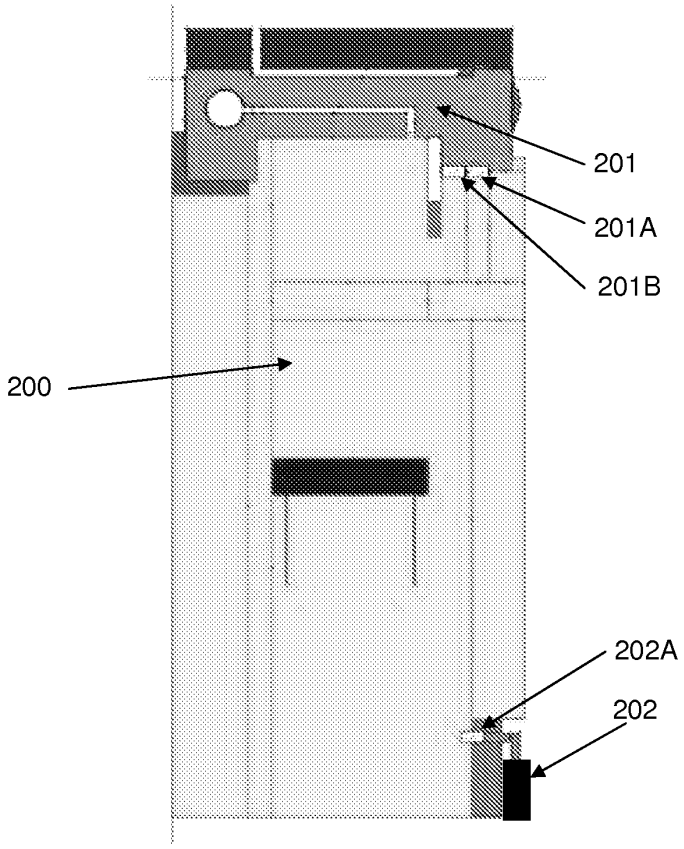


FIG. 2

(PRIOR ART)

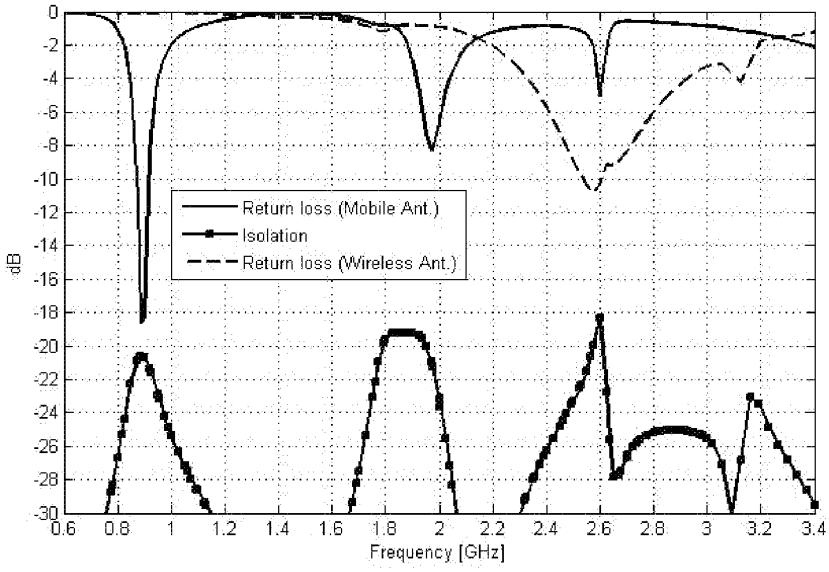


FIG. 3A

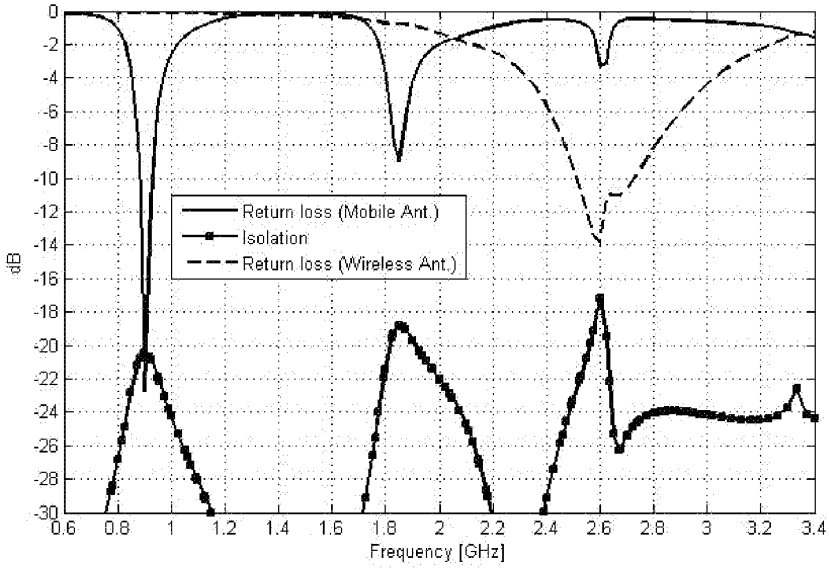


FIG. 3B

(PRIOR ART)

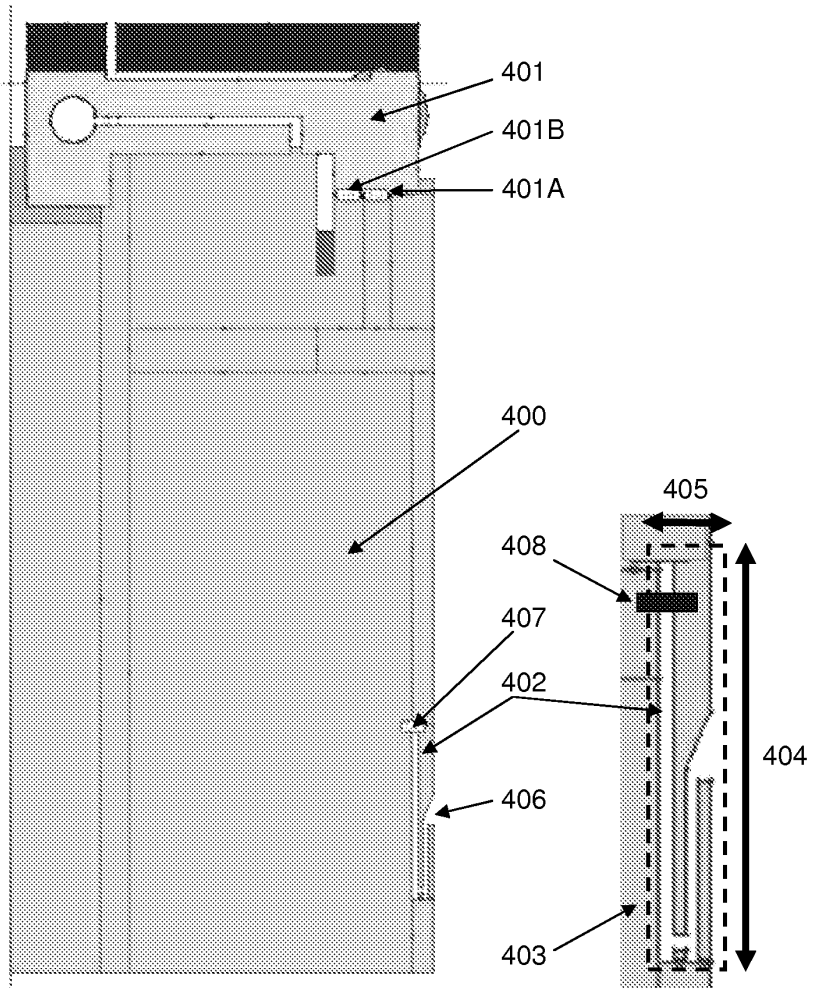


FIG. 4A FIG. 4B

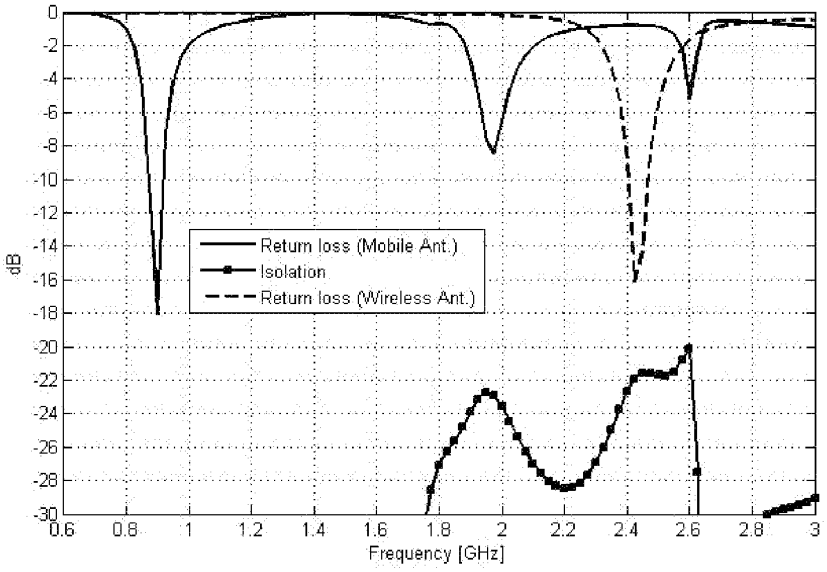

Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)
dB
Frequency [GHz]

FIG. 5A

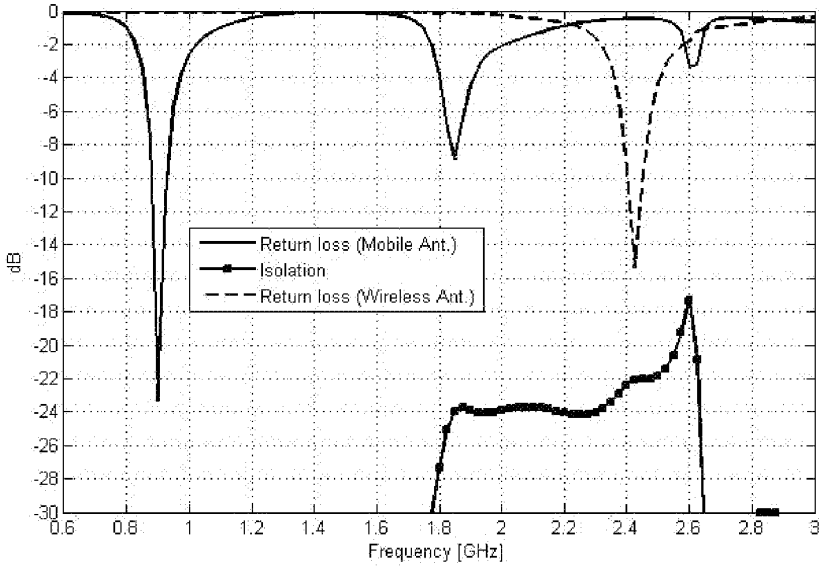

Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)
dB
Frequency [GHz]

FIG. 5B

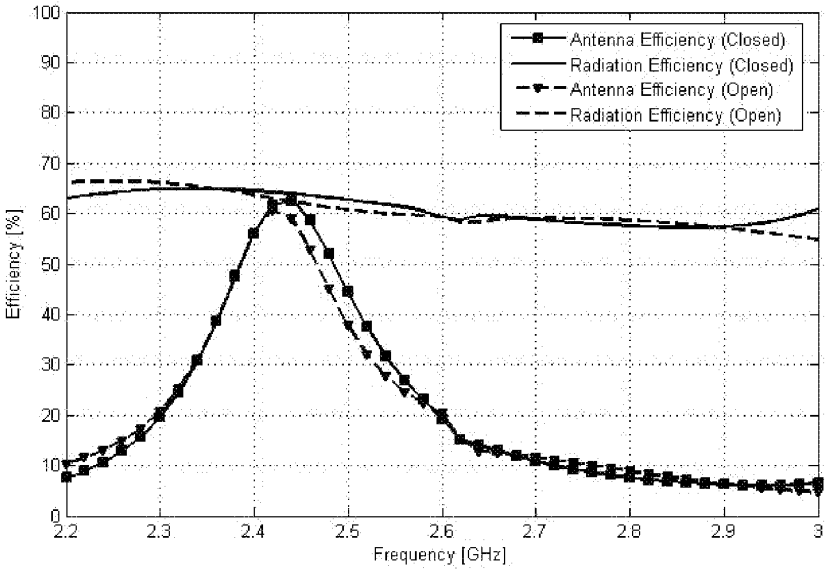

Antenna Efficiency (Closed)
Radiation Efficiency (Closed)
Antenna Efficiency (Open)
Radiation Efficiency (Open)
Efficiency [%]
Frequency [GHz]
100
90
80
70
60
50
40
30
20
10
0
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3

FIG. 6

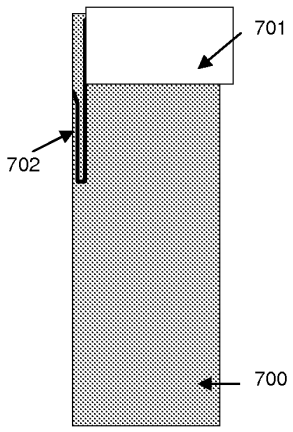


FIG. 7A

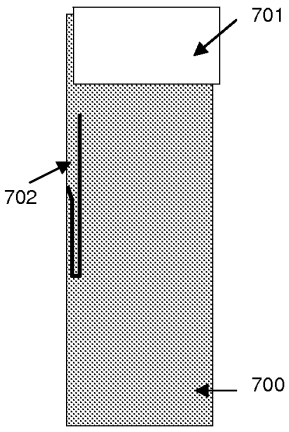


FIG. 7B

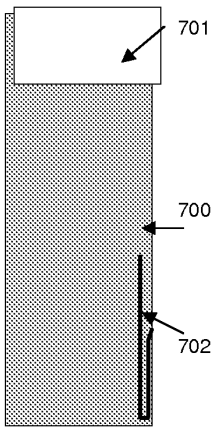


FIG. 7C

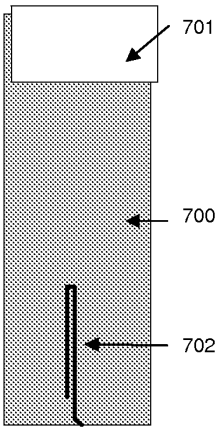


FIG. 7D

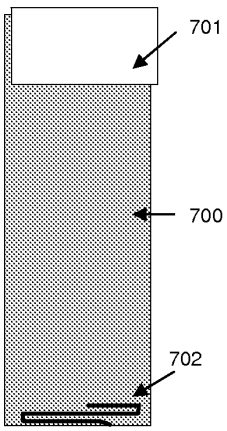


FIG. 7E

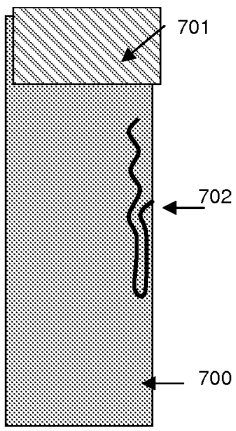


FIG. 7F

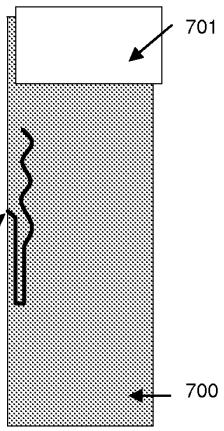


FIG. 7G

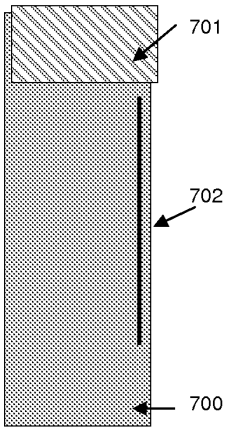


FIG. 7H

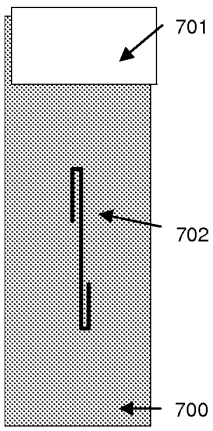


FIG. 7I

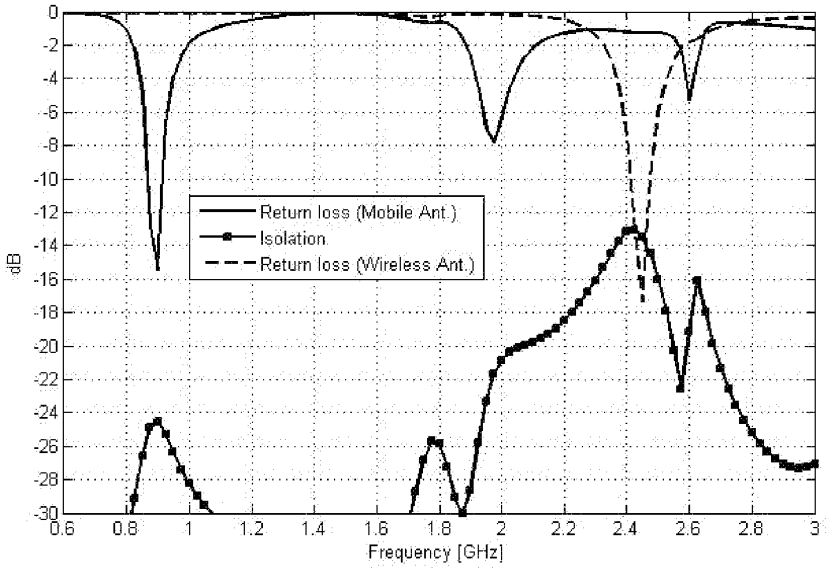

Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)
dB
Frequency [GHz]

FIG. 8A

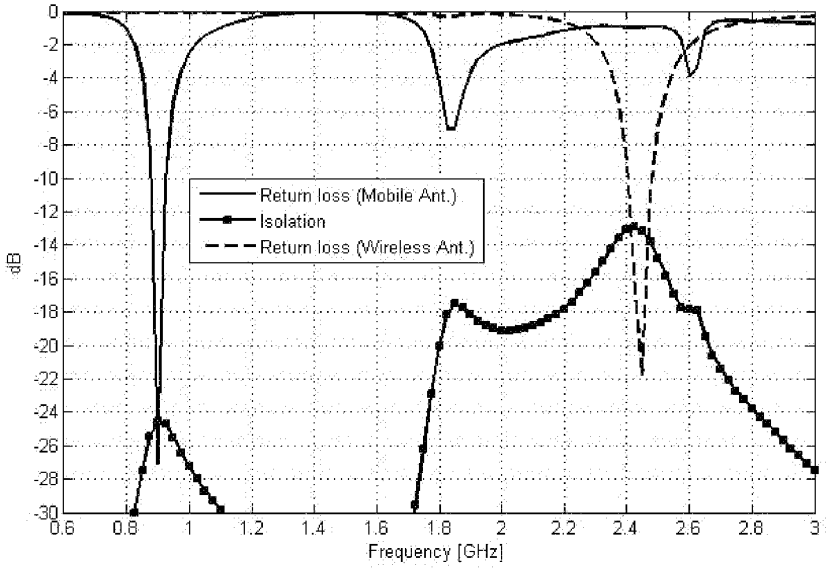

Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)
dB
Frequency [GHz]

FIG. 8B

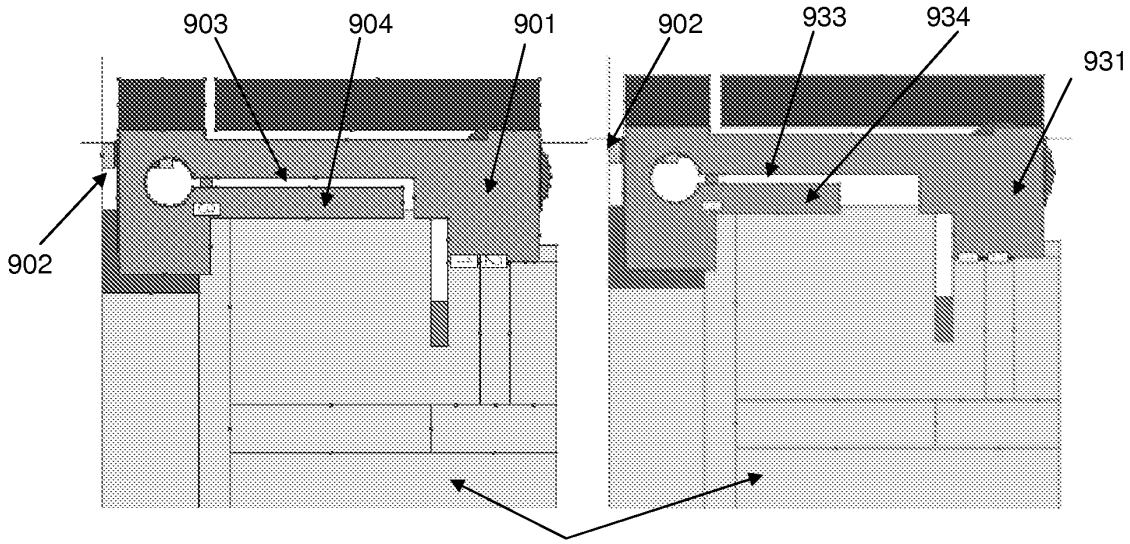


FIG. 9A FIG. 9B

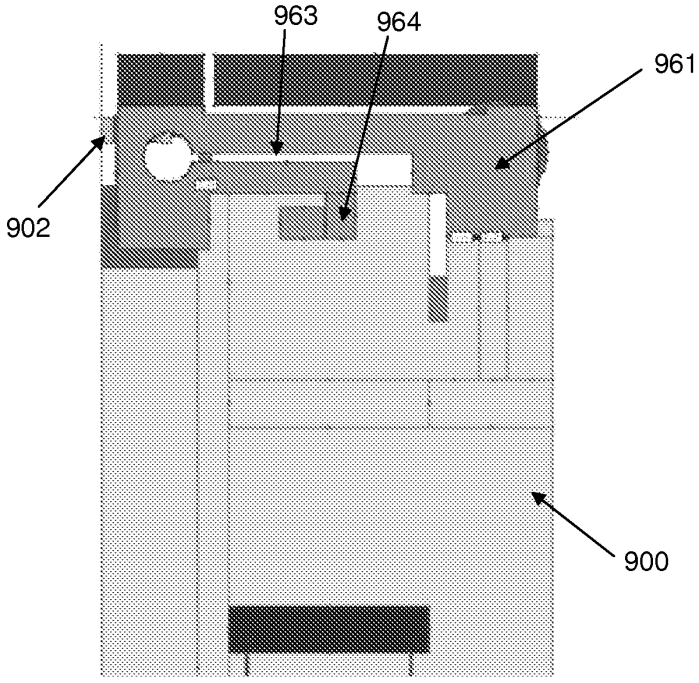


FIG. 9C

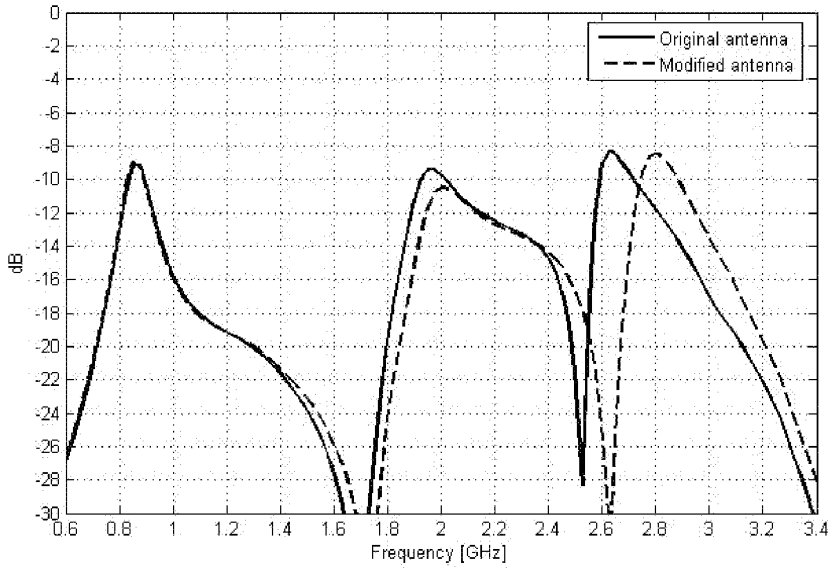

Original antenna
Modified antenna
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 10

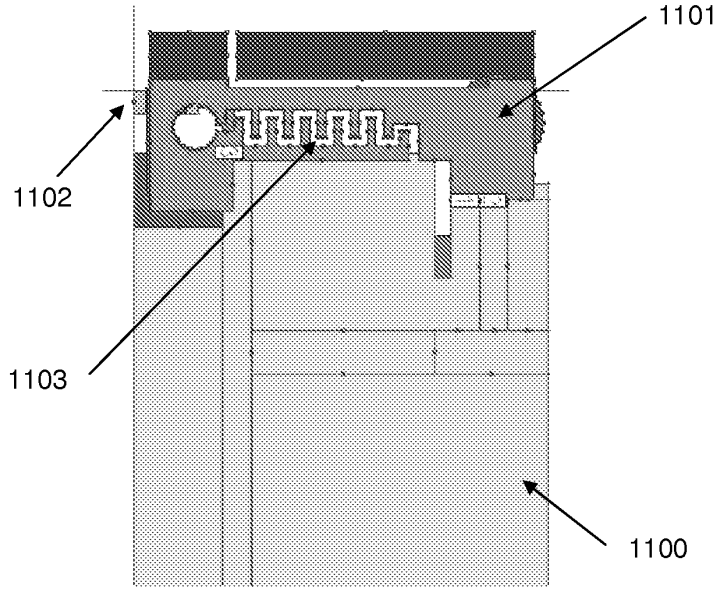


FIG. 11A

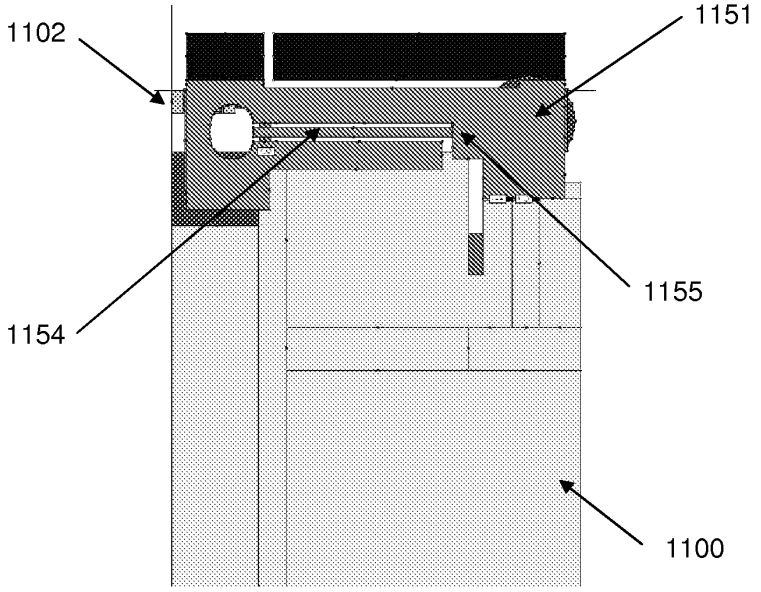


FIG. 11B

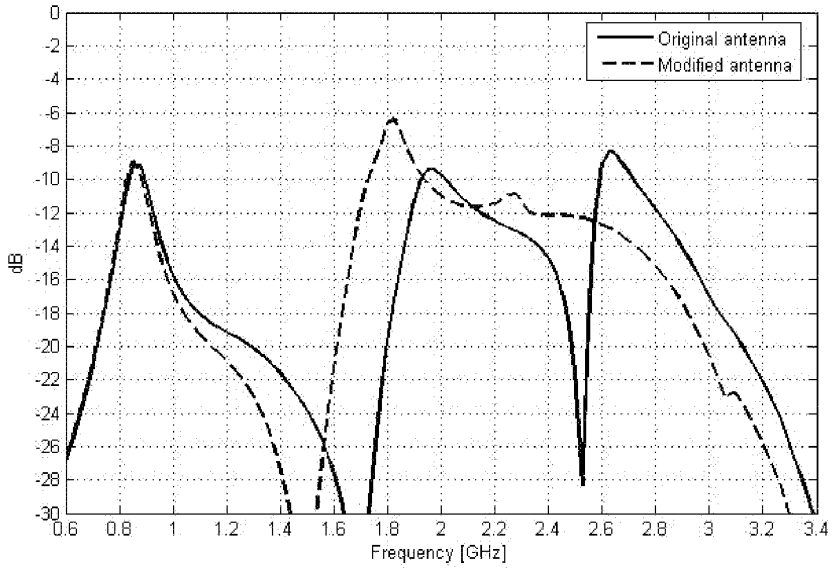

Original antenna
Modified antenna
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 12

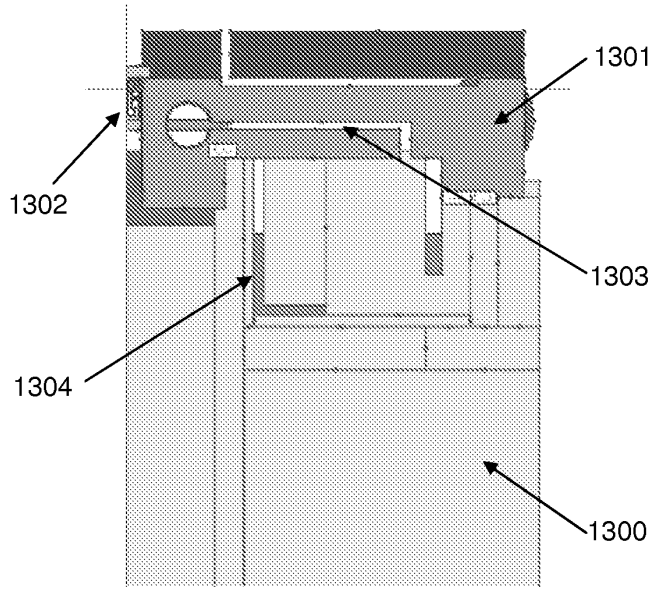


FIG. 13A

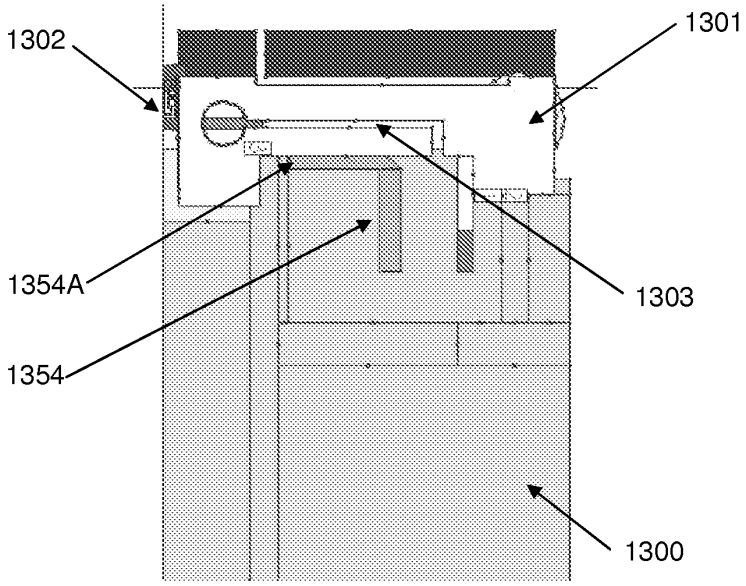


FIG. 13B

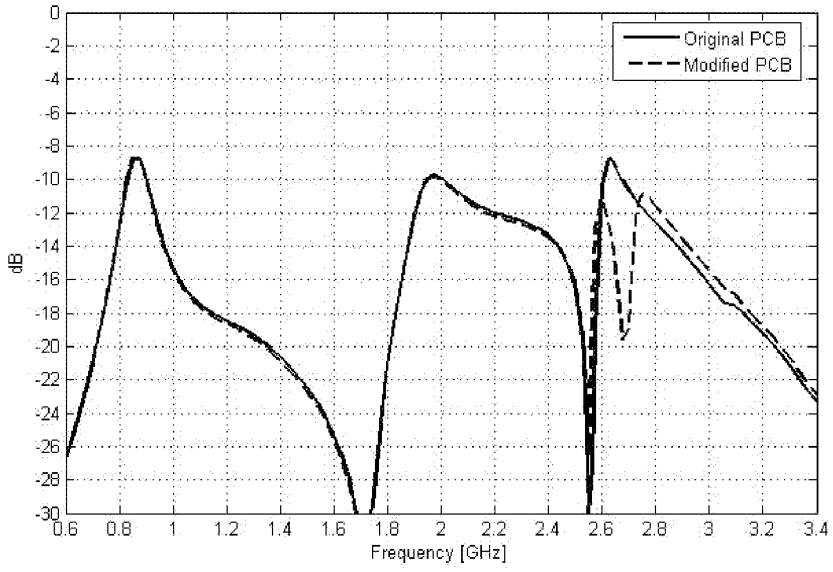

Original PCB
Modified PCB
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 14

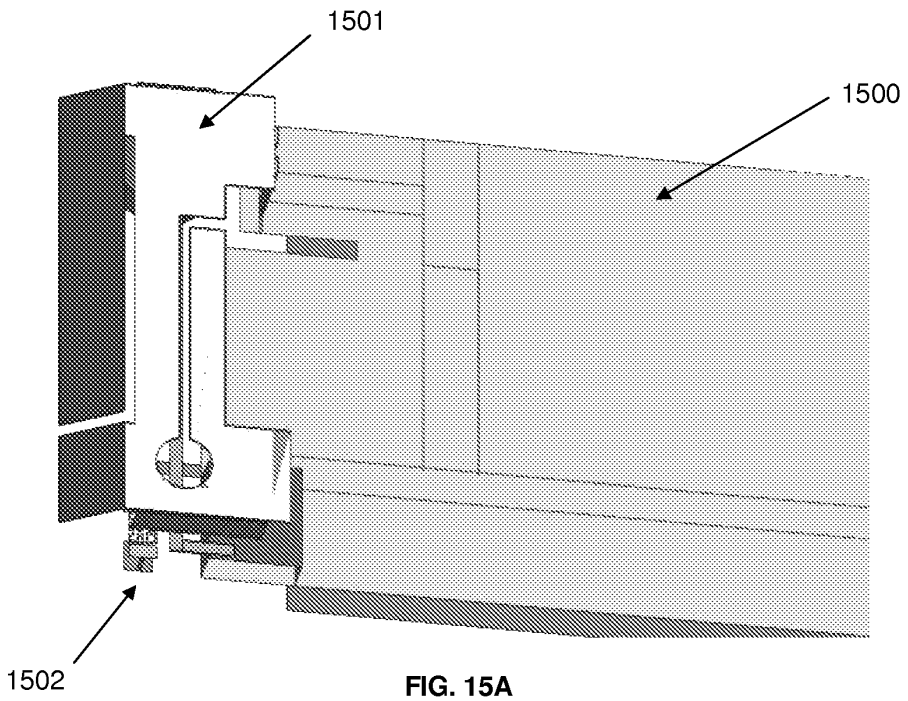


FIG. 15A

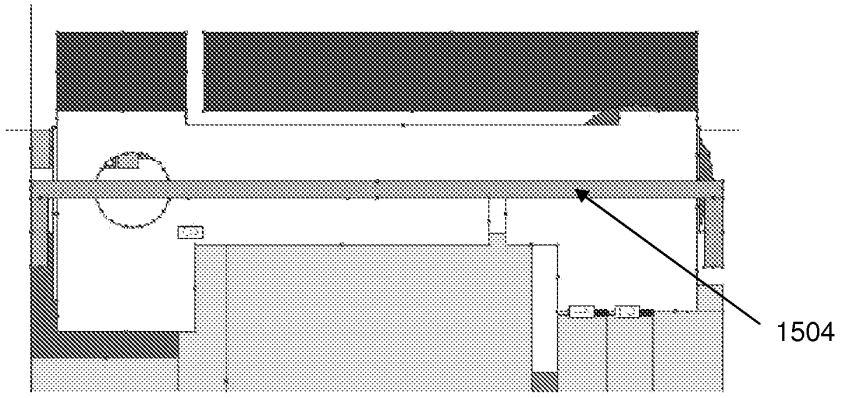


FIG. 15B

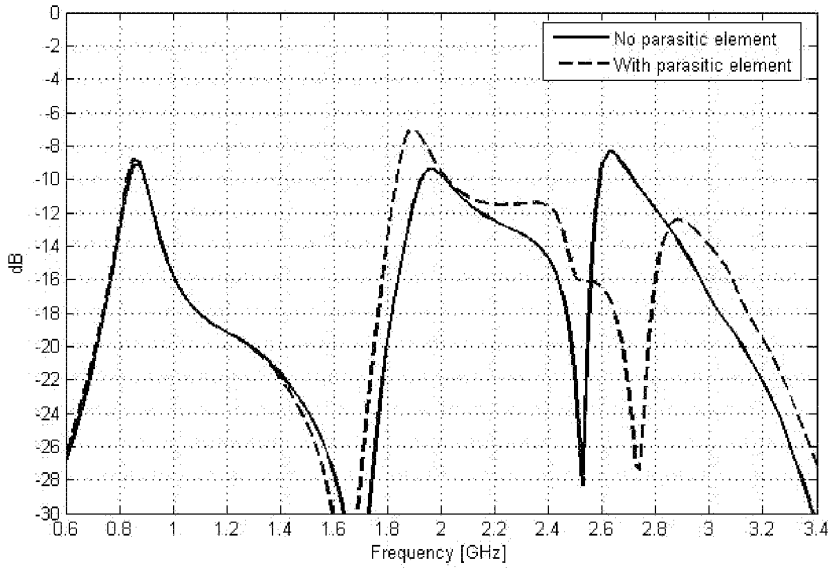

No parasitic element
With parasitic element
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 16

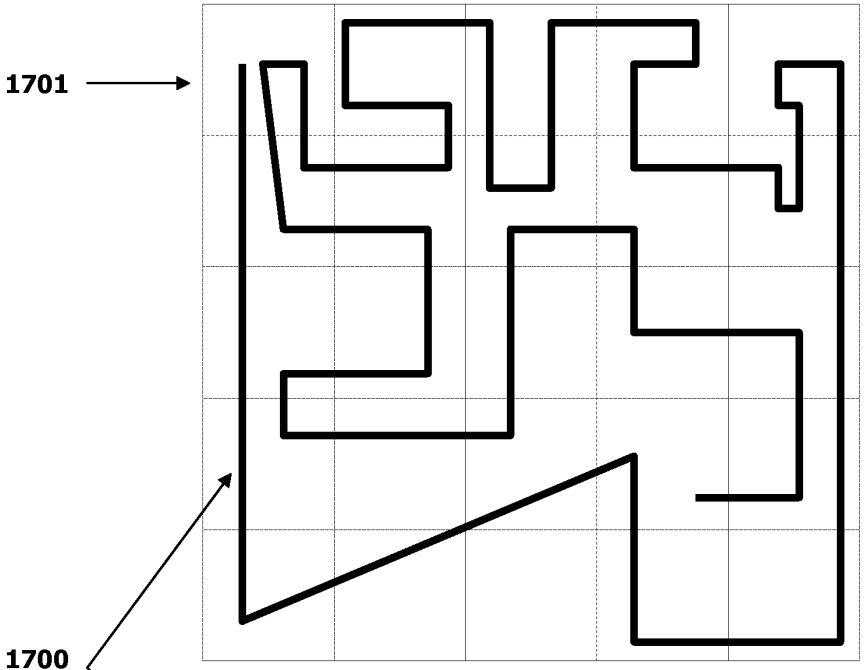


FIG. 17A

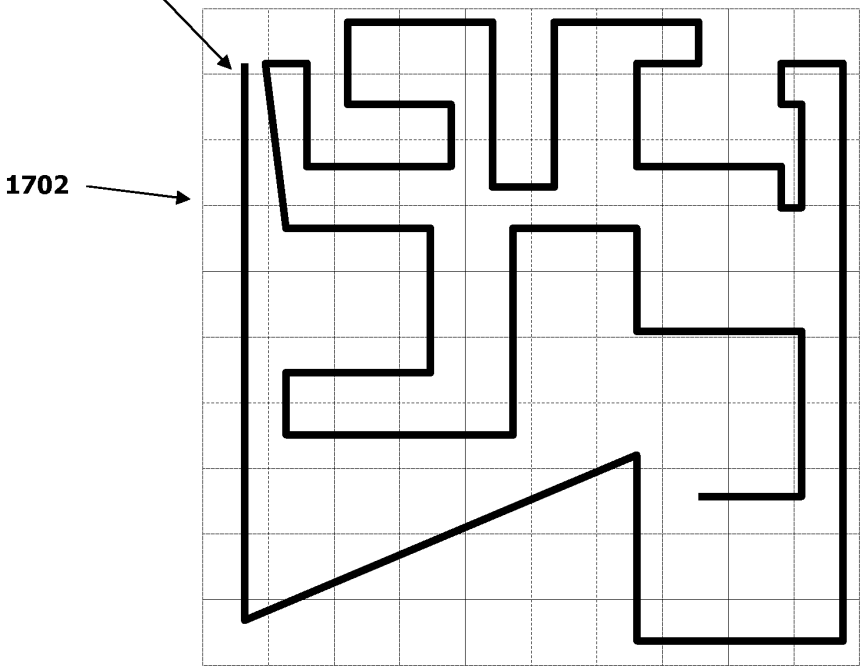


FIG. 17B

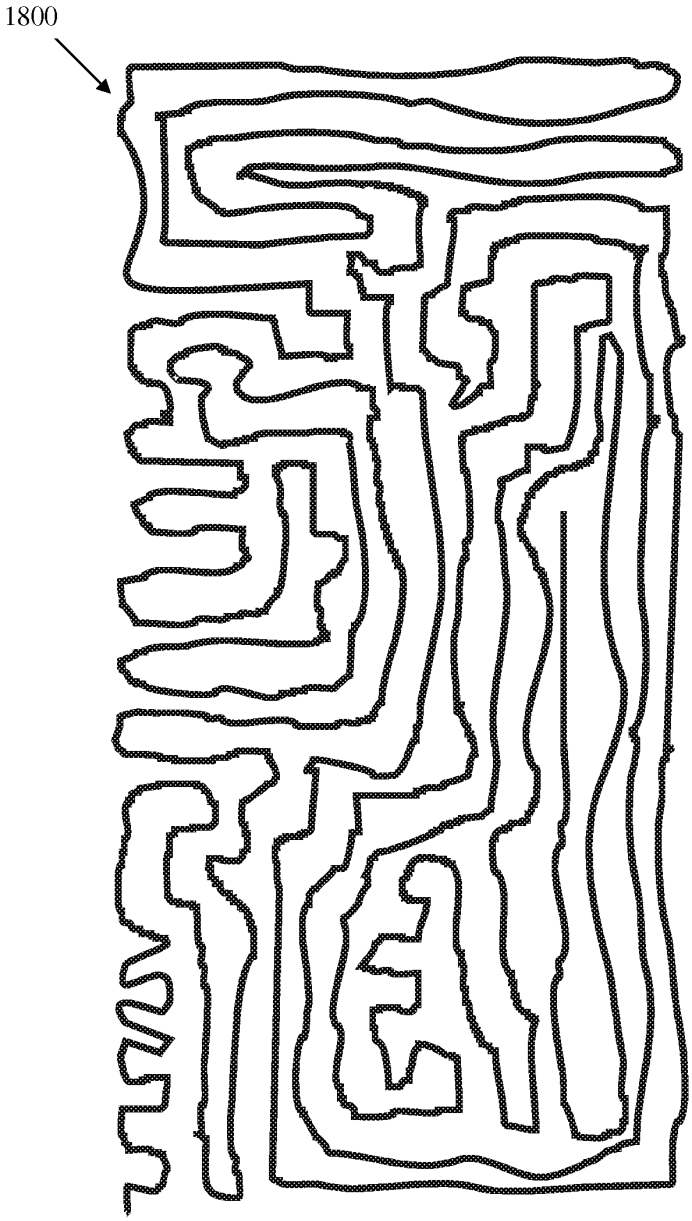


FIG. 18

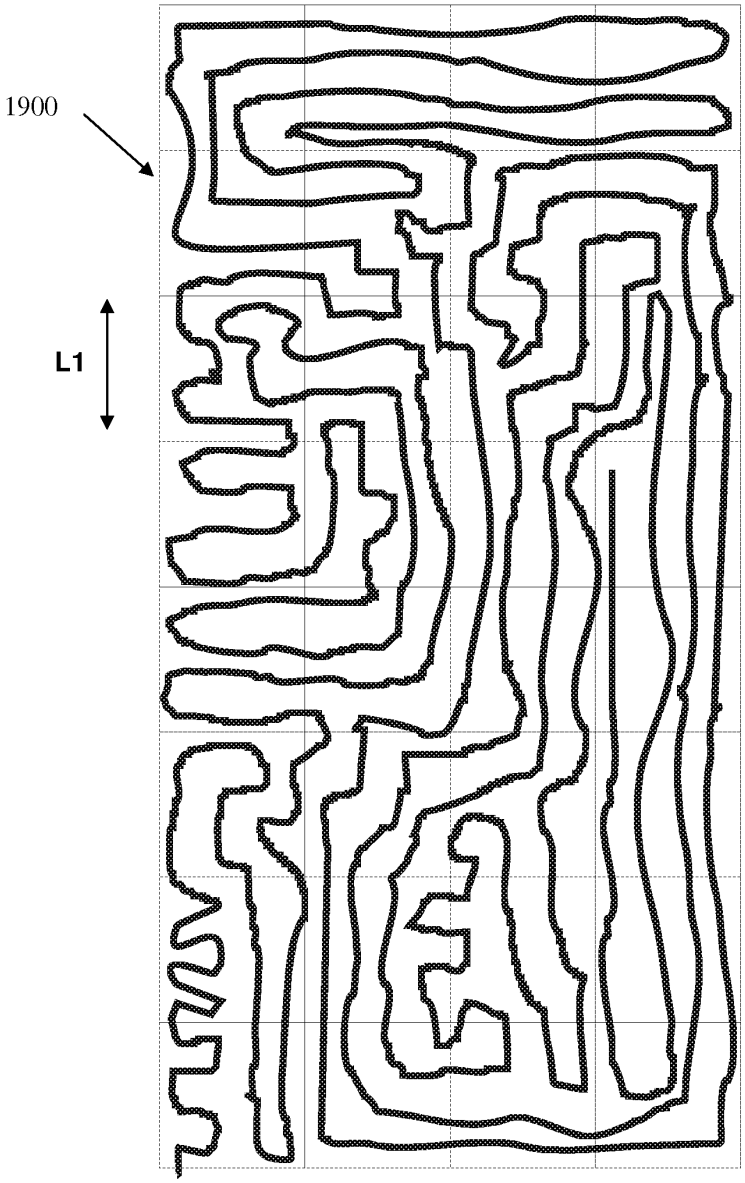


FIG. 19

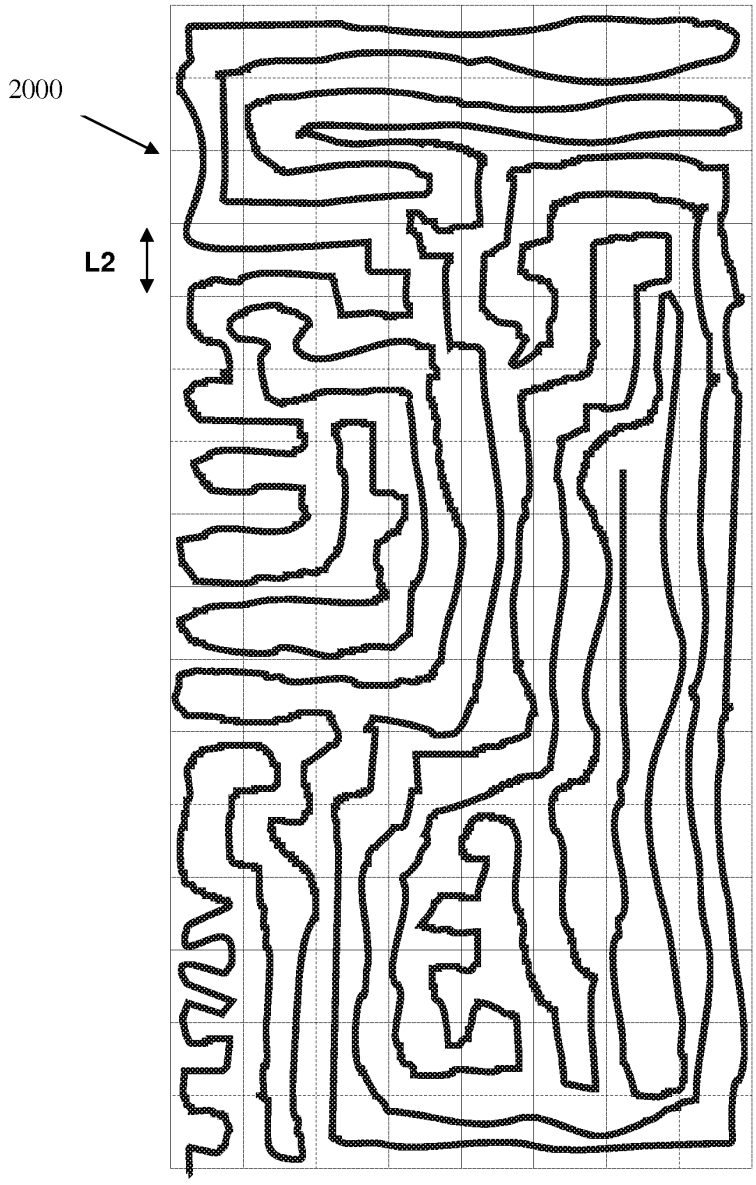


FIG. 20

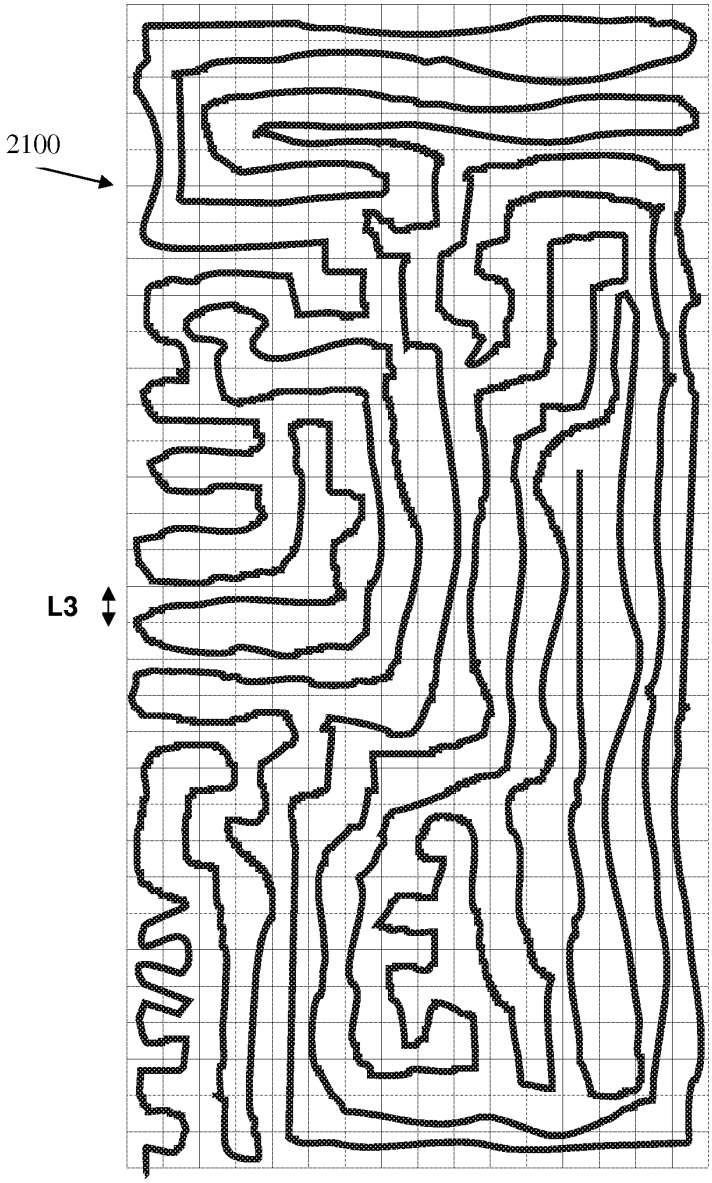


FIG. 21

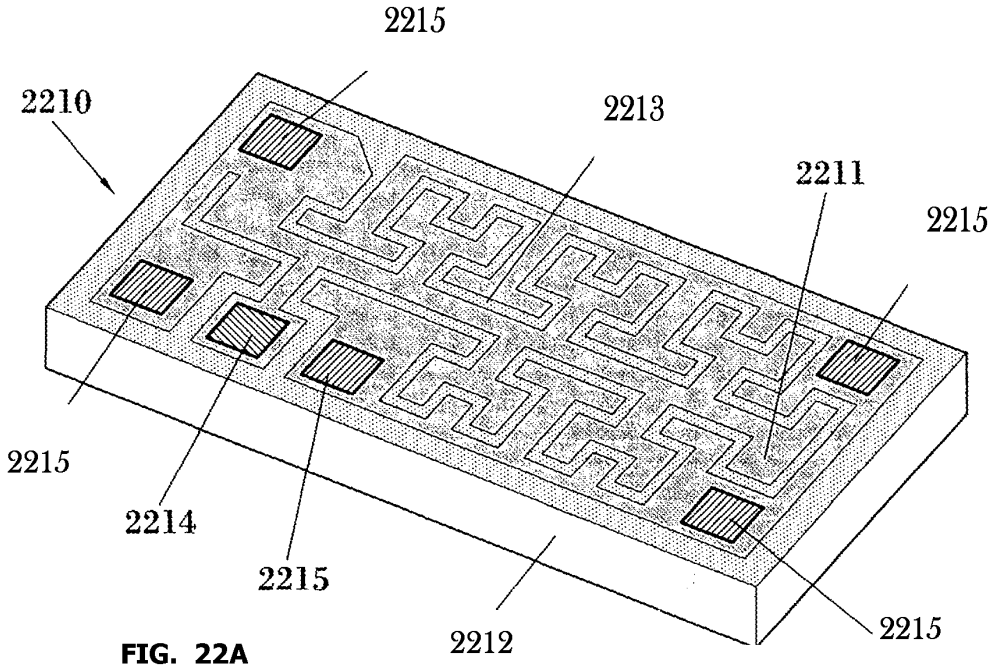


FIG. 22A

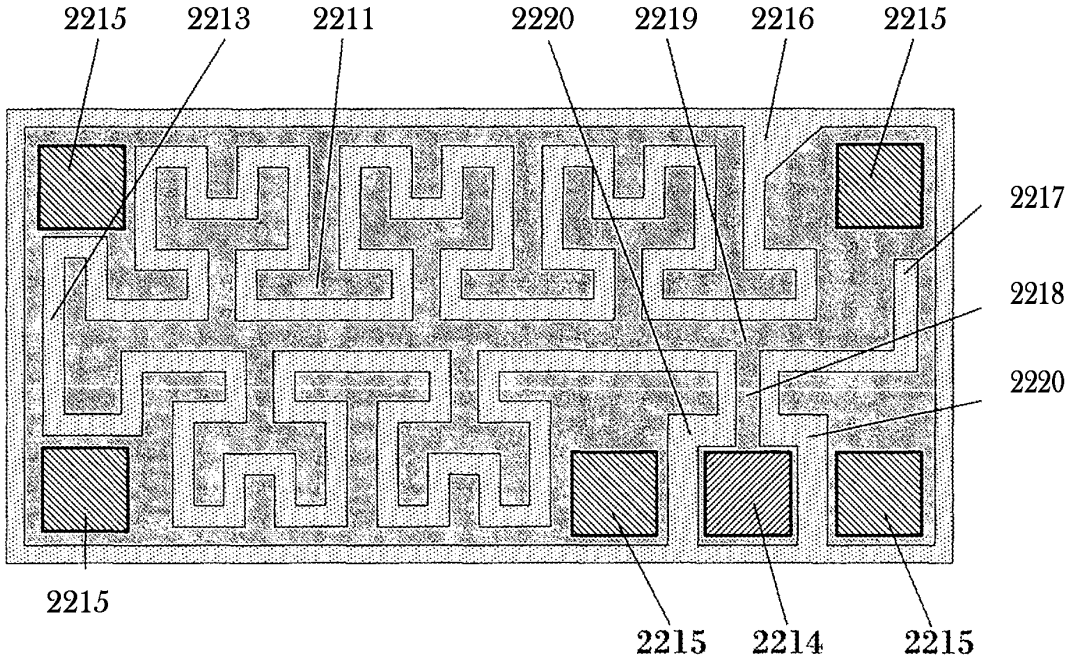


FIG. 22B

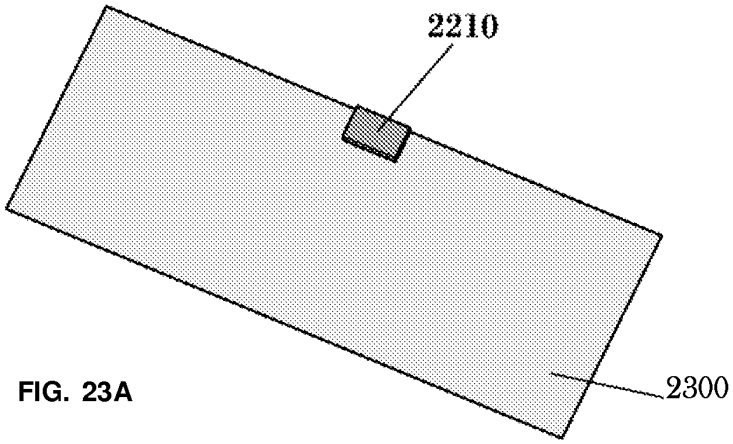


FIG. 23A

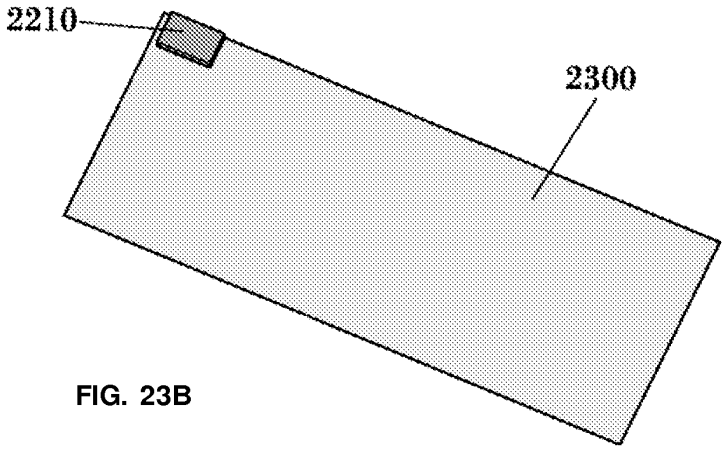


FIG. 23B

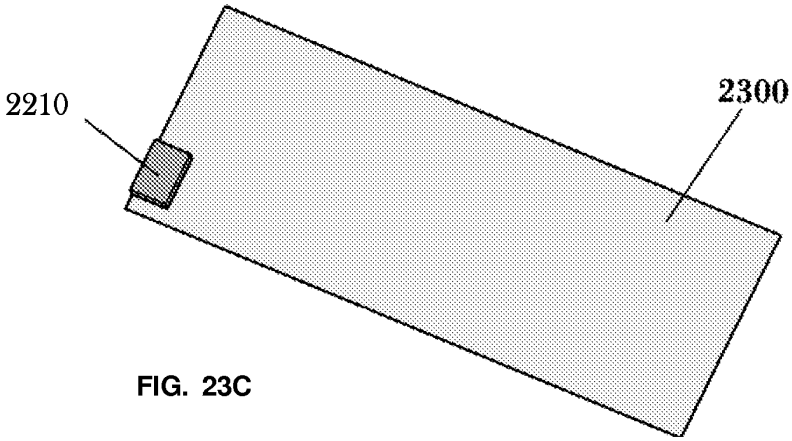


FIG. 23C

PTO/SB/22 (03-13)
Approved for use through 03/31/2013. OMB 0651-0031
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 if displays a valid OMB control number.

PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a)	Docket Number (Optional) 47005-P040WUSC2
Application Number 13/718,348-Conf. #8109	Filed December 18, 2012
For HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS	
Art Unit 2821	Examiner Not Yet Assigned

This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above-identified application.

The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):

	Fee	Small Entity Fee	Micro Entity Fee	
[x] One month (37 CFR 1.17(a)(1))	$200	$100	$50	$ 200.00
[ ] Two months (37 CFR 1.17(a)(2))	$600	$300	$150	$
[ ] Three months (37 CFR 1.17(a)(3))	$1,400	$700	$350	$
[ ] Four months (37 CFR 1.17(a)(4))	$2,200	$1,100	$550	$
[ ] Five months (37 CFR 1.17(a)(5))	$3,000	$1,500	$750	$

[ ] Applicant asserts small entity status. See 37 CFR 1.27.

[ ] Applicant certifies micro entity status. See 37 CFR 1.29.
Form PTO/SB/15A or B or equivalent must either be enclosed or have been submitted previously.

[ ] A check in the amount of the fee is enclosed.

[ ] Payment by credit card. Form PTO-2038 is attached.

[x] The Director has already been authorized to charge fees in this application to a Deposit Account.

[x] The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number 23-2426 .

[x] Payment made via EFS-Web.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

I am the

[ ] applicant/inventor.

[ ] assignee of record of the entire interest. See 37 CFR 3.71. 37 CFR 3.73(b) statement is enclosed (Form PTO/SB/96).

[x] attorney or agent of record. Registration number 61,654 .

[ ] attorney or agent acting under 37 CFR 1.34. Registration number _____ .

/Shoaib A. Mithani/	April 22, 2013
Signature	Date
Shoaib A. Mithani	(214) 745-5403
Typed or printed name	Telephone Number

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. Submit multiple forms if more than one signature is required, see below*.

[ ] *Total of 1 forms are submitted.

SCORE Placeholder Sheet for IFW Content

Application Number: 13718348 Document Date: 04/22/2013

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

- Drawings – Other than Black and White Line Drawings

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

To access the documents in the SCORE database, refer to instructions developed by SIRA.

At the time of document entry (noted above):

- Examiners may access SCORE content via the eDAN interface.
- Other USPTO employees can bookmark the current SCORE URL (http://es/ScoreAccessWeb/).
- External customers may access SCORE content via the Public and Private PAIR interfaces.

Form Revision Date: February 8, 2006

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
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2

CONFIRMATION NO. 8109

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

FORMALITIES LETTER

OC000000060772464

Date Mailed: 04/29/2013

NOTICE OF INCOMPLETE REPLY (NONPROVISIONAL)

Filing Date Granted

The U.S. Patent and Trademark Office has received your reply on 04/22/2013 to the Notice to File Missing Parts (Notice) mailed 01/23/2013 and it has been entered into the nonprovisional application. The reply, however, does not include the following items required in the Notice. A complete reply must be timely filed to prevent ABANDONMENT of the above-identified application. Replies should be mailed to: Mail Stop Missing Parts, Commissioner for Patents, P.O. Box 1450, Alexandria VA 22313-1450.

Applicant is given **TWO MONTHS** from the date of the Notice to File Missing Parts (Notice) mailed 01/23/2013 within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

Items Required to Avoid Abandonment:

The required items noted below SHOULD be filed along with any items required above. The filing date of this nonprovisional application will be the date of receipt of the items required above.

The application is informal since it does not comply with the regulations for the reason(s) indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- A substitute specification in compliance with 37 CFR 1.52, 1.121(b)(3), and 1.125, is required. The substitute specification must be submitted with markings and be accompanied by a clean version (without markings) as set forth in 37 CFR 1.125(c) and a statement that the substitute specification contains no new matter (see 37 CFR 1.125(b)). The specification, claims, and/or abstract page(s) submitted is not acceptable and cannot be scanned or properly stored because:
  - The application contains drawings, but the specification does not contain a brief description of the several views of the drawings as required by 37 CFR 1.74 and 37 CFR 1.77(b)(7).

Applicant is cautioned that correction of the above items may cause the specification and drawings page count to exceed 100 pages. If the specification and drawings exceed 100 pages, applicant will need to submit the required application size fee.

Replies must be received in the USPTO within the set time period or must include a proper Certificate of Mailing or Transmission under 37 CFR 1.8 with a mailing or transmission date within the set time period. For more information and a suggested format, see Form PTO/SB/92 and MPEP 512.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

/ygizaw/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/718,348

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	280
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	600
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720
TOTAL CLAIMS (37 CFR 1.16(i))	20 minus 20 =	*			OR	x 80 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*				x 420 =	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	1600

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($)	ADDITIONAL FEE($)	OR	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

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
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2

CONFIRMATION NO. 8109

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

MISCELLANEOUS NOTICE

OC000000060772307

Date Mailed: 04/29/2013

A communication which cannot be delivered in electronic form has been mailed to the applicant.

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
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2

CONFIRMATION NO. 8109

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

POA ACCEPTANCE LETTER

OC000000060746083

Date Mailed: 04/29/2013

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 02/01/2013.

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.

/tchaka/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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 DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2

CONFIRMATION NO. 8109

OC000000060772307

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

Date Mailed: 04/29/13

NOTICE OF INCOMPLETE REPLY

Filing Date Granted

Applicant's reply to the Notice mailed on 01/23/13 was received in the U.S. Patent and Trademark Office on 04/22/13 and has been entered into the application. The reply, however, does not include the following item(s) required in the Notice.

The period for reply continues to run from the mailing date of the prior Notice. The item(s) listed below must be timely filed to avoid abandonment of the application. No new time period for reply is provided in this communication. If the period for reply set forth in the prior Notice has expired, this application will become abandoned unless applicant: (1) submits the following checked item(s), **and** (2) obtains an extension of time under 37 CFR 1. 136(a) (including the appropriate fee (37 CFR 1.17(a)). In no case may an applicant obtain an extension of time for more than FIVE (5) MONTHS beyond the date for reply set forth in the prior Notice.

A complete reply which includes the following checked item(s) must be timely filed to prevent ABANDONMENT of the above-identified application:

- ☐ A substitute specification.
- ☒ A statement that the substitute specification contains no new matter.
- ☐ A replacement abstract commencing on a separate sheet in compliance with 37 CFR 1.72(b) and 1.121 (deleting the drawings or flow diagrams).
- ☐ New and replacement drawing sheets.
- ☐ Replacement drawing sheets with the figures renumbered.
- ☐ A complete claim listing or a replacement claim listing with the claims renumbered.
- ☐ An amendment to the claims in compliance with 37 CFR 1.121 (deleting the drawings or flow diagrams).
- ☐ A replacement transmittal letter listing all of the files except the missing or unreadable file.
- ☐ A duplicate copy of the CD.
- ☐ A statement that the replacement CD contains no new matter.

Rev. 12/2008

Replies should be mailed to: Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

For more information about EFS-Web, please call the USPTO Electronic Business Center at 1-866-217-9197 or visit our website at http://www.uspto.gov/ebc.

Application Assistance Unit (571) 272-4200

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: May 22, 2013
Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

Docket No.: 47005-P040WUSC2
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Joseph Mumbru et al.

Application No.: 13/718,348 | Confirmation No.: 8109

Filed: December 18, 2012 | Art Unit: 2821

For: HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS | Examiner: Not Yet Assigned

RESPONSE TO NOTICE OF INCOMPLETE REPLY

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

Dear Madam:

In response to the Notice of Incomplete Reply and the Notice to File Corrected Application Papers – Filing Date Granted mailed January 23, 2013, Applicant respectfully submits a Substitute Specification (marked up and clean versions) and Drawing(s) (45 figures, 23 pages). Applicant respectfully submits that no new matter has been added by the amendments to the Substitute Specification.

Applicant submitted the executed declaration on February 1, 2013 and paid the required fee amount of $130.00.

Please charge Deposit Account No. 23-2426 in the amount of $400.00 for the two month extension of time (one month extension of time fee $200 previously paid). 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-P040WUSC2.

Dated: May 22, 2013

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 Patent Application Fee Transmittal

Application Number:	13718348
Filing Date:	18-Dec-2012
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-P040WUSC2

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:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 2 months with $200 paid	1252	1	400	400

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
			Total in USD ($)	**400**

Electronic Acknowledgement Receipt	
EFS ID:	15838629
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	22-MAY-2013
Filing Date:	18-DEC-2012
Time Stamp:	09:58:09
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$400
RAM confirmation Number	8270
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 1.19 (Document supply fees) Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)	

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	Specification	CleanVersion_1.PDF	231081 a26781de1e1f868e916e4d24ef682d85dd47ed77	no	46
Warnings:					
Information:					
2	Specification	MarkedUp_2.PDF	237683 d3c45c084b563f1abd03885b5c8c32d457b3f1f4	no	46
Warnings:					
Information:					
3	Drawings-other than black and white line drawings	Drawings_3.PDF	4229688 c88111ca93558f6431ad8656f5e5b2c76d2e9bf7	no	23
Warnings:					
Information:					
4	Miscellaneous Incoming Letter	Response_4.PDF	20580 2ddf2dcbe16b9ed7d72363b2873dc7f9bcc05b7e	no	2
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	30540 b1aba8a814d448ab4655957880f470e1b4f73063	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	4749572		

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.

CLEAN VERSION OF SUBSTITUTE SPECIFICATION

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 Figs. 1(A-B)). 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 Fig. 2. For this example, the handset has been selected to have a slider-type topology as schematically illustrated in Figs. 1(A-B). 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 Fig. 1A or in an open position, as shown in Fig. 1B. 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 Figs. 1(A-B)). 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 Fig. 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 Fig. 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 Fig. 2 are shown without any limiting purpose in Figs. 3(A-B). Fig. 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 Fig. 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.

Figs. 17(A-B) 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.

Fig. 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 Fig. 18 enclosed in a first grid 1900 having thirty-two (32) square cells, each with a length L1. Fig. 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 Fig. 19 and Fig. 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 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:

Figs. 1(A-B) – 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): **(Fig. 1A)** General view of the PCBs of the handset in the closed position; and **(Fig. 1B)** 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.

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

Figs. 4(A-B) – 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: **(Fig. 4A)** General view of the PCB of the handset carrying the two antennas; and **(Fig. 4B)** detailed view of the region that contains the slot antenna.

Figs. (A-B) – Typical electrical performance of the antennas of the handset shown in Figs. (A-B): **(Fig. 5A)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and **(Fig. 5B)** 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 (A-I) – 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.

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

Figs. 9(A-C) 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 **(Fig. 9B)** modifying the dimensions of an arm of the mobile antenna; or **(Fig. 9C)** 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.

Figs. 11(A-B) – 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: **(Fig. 11A)** shaping the slot as a meander-like curve; or **(Fig. 11B)** 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.

Figs. 13(A-B) – 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: **(Fig. 13A)** introducing a slot on the PCB; or **(Fig. 13B)** 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.

Figs. 15(A-B) – 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: **(Fig. 15A)** General view of the PCB of the handset; and **(Fig. 15B)** 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 Figs. 15(A-B), in the handset.

Figs. 17(A-B) – Example of a box counting curve located in a first grid **(Fig. 17A)** of 5x5 boxes and in a second grid **(Fig. 17B)** 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.

Figs. 22(A-B) – Example of a slot antenna component.

Figs. 23(A-C) – 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 Figs. 4(A-B)). In the example of Figs. 4(A-B), 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 Figs. 4(A-B)). 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 Figs. 4(A-B), 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 Figs. 7(A-I)). 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.

Figs. 5(A-B) presents, without any limiting purpose, an example of electrical results for the handset of Figs. 4(A-B) according to the present invention. Fig. 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 Fig. 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 Figs. 4(A-B) is better than the results obtained for the example of a conventional prior-art arrangement in Fig. 2. A typical radiation performance of the slot antenna (402) is shown without any limiting purpose in Fig. 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.

Figs. 7(A-I) present, 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 Fig. 7C is expected to be better than for the case of Fig. 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 Fig. 7B is presented without any limiting purpose in Figs. 8(A-B). As it can be observed, the return loss of each antenna is practically the same as the one already presented in Figs. 5(A-B). 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 Fig. 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 Fig. 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 Fig. 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 Fig. 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 Fig. 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). Fig. 10 presents without any

limiting purpose a typical antenna isolation that can be obtained with a modified mobile antenna like the one in Fig. 9C, and compares it with the isolation obtained with the original mobile antenna (Fig. 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. Figs. 11(A-B) 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 Fig. 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 Fig. 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). Fig. 12 presents without any limiting purpose a typical antenna isolation that can be obtained with a modified mobile antenna like the one in Fig. 11B, and compares it with the isolation obtained with the original mobile antenna (Fig. 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.

Fig. 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 Fig. 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.

Fig. 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 Fig. 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).

Fig. 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 Fig. 13B. Compared with the isolation curve obtained in the original handset (Fig. 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 Fig. 13A, or two or more conducting strips shorted to the ground plane of the PCB, like the conducting stripe (1354) in Fig. 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 Fig. 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 Fig. 15(A-B), 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 Fig. 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 Figs. 13(A-B) and 15(A-B)) 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.

Figs. (A-B) 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 Figs. 22(A-B), 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 Figs. 22(A-B), 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 90º), however said connection could also occur at angles smaller or larger than 90º.

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.

Figs. 22(A-B) 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 Figs. 22(A-B), 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 Figs. 23(A-B) 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 Figs. 23(A-C), 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.

MARKED UP VERSION OF SUBSTITUTE SPECIFICATION

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~~ Figs. 1(A-B)). 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~~ Fig. 2. For this example, the handset has been selected to have a slider-type topology as schematically illustrated in ~~Figure 1~~ Figs. 1(A-B). 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 1a~~ Fig. 1A or in an open position, as shown in ~~Figure 1b~~ Fig. 1B. 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~~ Figs. 1(A-B)). 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~~ Fig. 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~~ Fig. 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~~ Fig. 2 are shown without any limiting purpose in ~~Figure 3~~ Figs. 3(A-B). ~~Figure 3a~~ Fig. 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~~ Fig. 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~~ Figs. 17(A-B) 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~~ Fig. 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~~ Fig. 18 enclosed in a first grid 1900 having thirty-two (32) square cells, each with a length L1. ~~Figure~~ Fig. 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~~ Fig. 19 and ~~Figure~~ Fig. 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~~ 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~~ 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**~~ **Figs. 1(A-B)** – 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)**~~ **(Fig. 1A)** General view of the PCBs of the handset in the closed position; and ~~**(b)**~~ **(Fig. 1B)** 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**~~ **Figs. 3(A-B)** – Typical electrical performance of the antennas of the handset shown in ~~**(a)**~~ **Fig. 3A:** Return loss of each antenna and isolation between antennas when the handset is in closed position; and ~~**(b)**~~ **(Fig. 3B)** return loss of each antenna and isolation between antennas when the handset is in open position.

~~**Fig. 4**~~ **Figs. 4(A-B)** – 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)**~~ **(Fig. 4A)** General view of the PCB of the

handset carrying the two antennas; and ~~(b)~~ **(Fig. 4B)** detailed view of the region that contains the slot antenna.

~~**Fig. 5**~~ **Figs. (A-B)** – Typical electrical performance of the antennas of the handset shown in ~~Fig. 4~~ Figs. (A-B): ~~(a)~~ **(Fig. 5A)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and ~~(b)~~ **(Fig. 5B)** 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 (A-I) – 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**~~ **Figs. 8(A-B)** – Typical electrical performance of the antennas of the handset shown in ~~Figure 7b~~ Fig. 7B: ~~(a)~~ **(Fig. 8A)** Return loss of each antenna and isolation between antennas when the handset is in closed position; and ~~(b)~~ **(Fig. 8B)** return loss of each antenna and isolation between antennas when the handset is in open position.

~~**Fig. 9 – (a)**~~ **Figs. 9(A-C)** 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)~~ **(Fig. 9B)** modifying the dimensions of an arm of the mobile antenna; or ~~(c)~~ **(Fig. 9C)** 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~~ 9B.

~~**Fig. 11**~~ **Figs. 11(A-B) –** 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)**~~ **(Fig. 11A)** shaping the slot as a meander-like curve; or ~~**(b)**~~ **(Fig. 11B)** 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~~ 11B.

~~**Fig. 13**~~ **Figs. 13(A-B) –** 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)**~~ **(Fig. 13A)** introducing a slot on the PCB; or ~~**(b)**~~ **(Fig. 13B)** 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~~ 13B.

~~**Fig. 15**~~ **Figs. 15(A-B) –** 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)**~~ **(Fig. 15A)** General view of the PCB of the handset; and ~~**(b)**~~ **(Fig. 15B)** 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~~ 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~~ Figs. 15(A-B), in the handset.

~~**Fig. 17**~~ **Figs. 17(A-B) –** Example of a box counting curve located in a first grid **(Fig. 17A)** of 5x5 boxes and in a second grid **(Fig. 17B)** 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**~~ **Figs. 22(A-B)** – Example of a slot antenna component.

~~**Fig. 23**~~ **Figs. 23(A-C)** – 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~~ Figs. 4(A-B)). In the example of ~~Figure 4~~ Figs. 4(A-B), 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~~ Figs. 4(A-B)). 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~~ Figs. 4(A-B), 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~~

Figs. 7(A-I)). 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.

~~Fig. 5~~ Figs. 5(A-B) presents, without any limiting purpose, an example of electrical results for the handset of ~~Fig. 4~~ Figs. 4(A-B) according to the present invention. ~~Figure 5a~~ Fig. 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~~ Fig. 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~~ Figs. 4(A-B) is better than the results obtained for the example of a conventional prior-art arrangement in ~~Figure~~ Fig. 2. A typical radiation performance of the slot antenna (402) is shown without any limiting purpose in ~~Figure~~ Fig. 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~~ Figs. 7(A-I) present, 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~~ Fig. 7C is expected to be better than for the case of ~~Figure 7a~~ Fig. 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~~ Fig. 7B is presented without any limiting purpose in ~~Figure 8~~ Figs. 8(A-B). As it can be observed, the return loss of each antenna is practically the same as the one already presented in ~~Figure 5~~ Figs. 5(A-B). 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 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 ~~Figure 9a~~ Fig. 9A, where the tip of arm (904) defined the open end of the slot (903). ~~Figure~~ Fig. 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~~ Fig. 9C, and compares it with the isolation obtained with the original mobile antenna ~~Figure 9a~~ (Fig. 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~~ Figs. 11(A-B) 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 11B, and compares it with the isolation obtained with the original mobile antenna ~~Figure 9a~~ (Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 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~~ Fig. 13B. Compared with the isolation curve obtained in the original handset ~~Figure 9a~~ (Fig. 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~~ Fig. 13A, or two or more conducting strips shorted to the ground plane of the PCB, like the conducting stripe (1354) in ~~Figure 13b~~ Fig. 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~~ Fig. 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~~ Fig. 15(A-B), 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~~ Fig. 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 ~~Figures13 and 15~~ Figs. 13(A-B) and 15(A-B)) 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~~ Figs. (A-B) 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~~ 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~~ 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~~ Figs. 22(A-B), 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 ~~Fig. 22~~ Figs. 22(A-B), 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 90º), however said connection could also occur at angles smaller or larger than 90º.

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.

~~Fig. 22~~ Figs. 22(A-B) 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~~ Figs. 22(A-B), 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~~ Figs. 23(A-B) 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~~ 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~~ 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~~ 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~~ Figs. 23(A-C), 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.

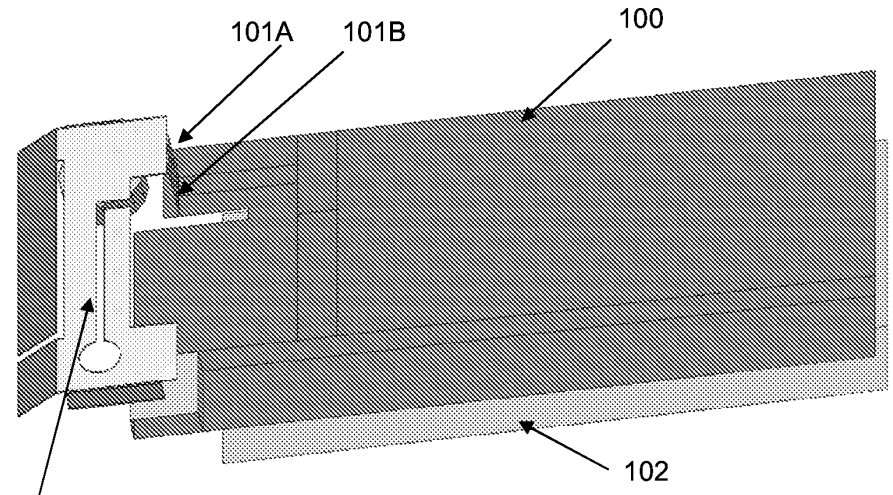


FIG. 1A

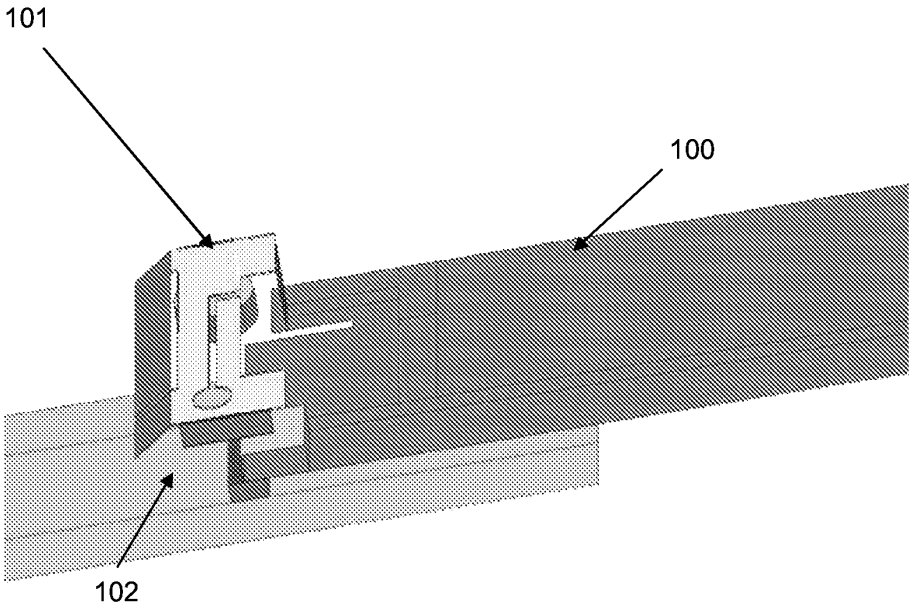


FIG. 1B

(PRIOR ART)

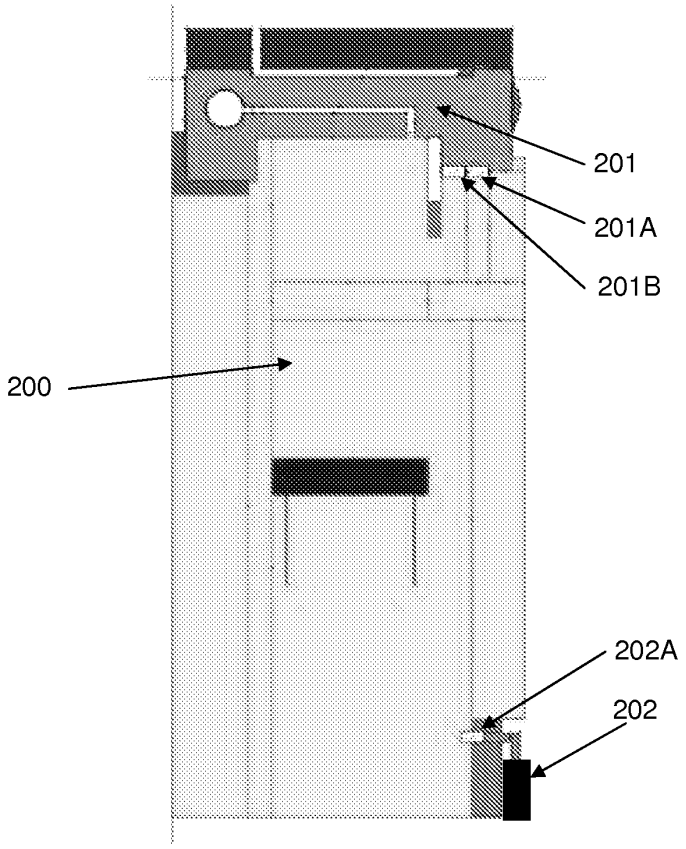


FIG. 2

(PRIOR ART)

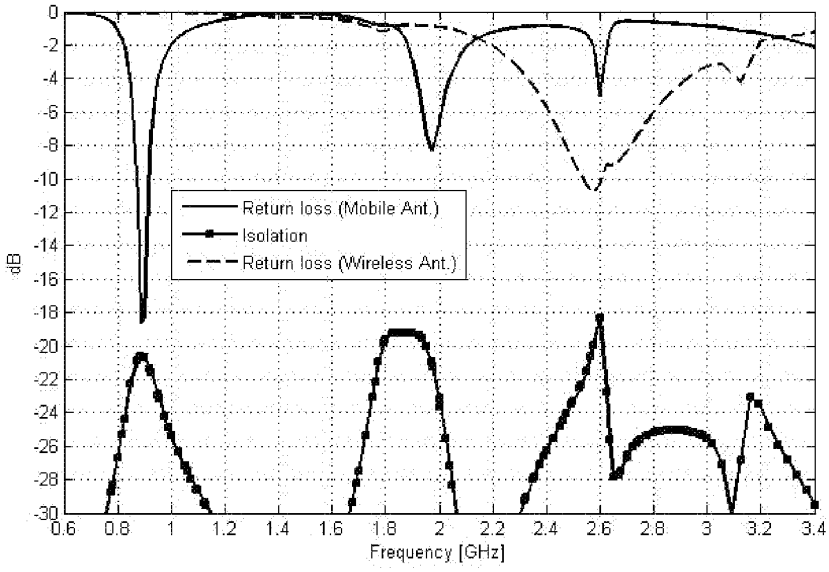


FIG. 3A

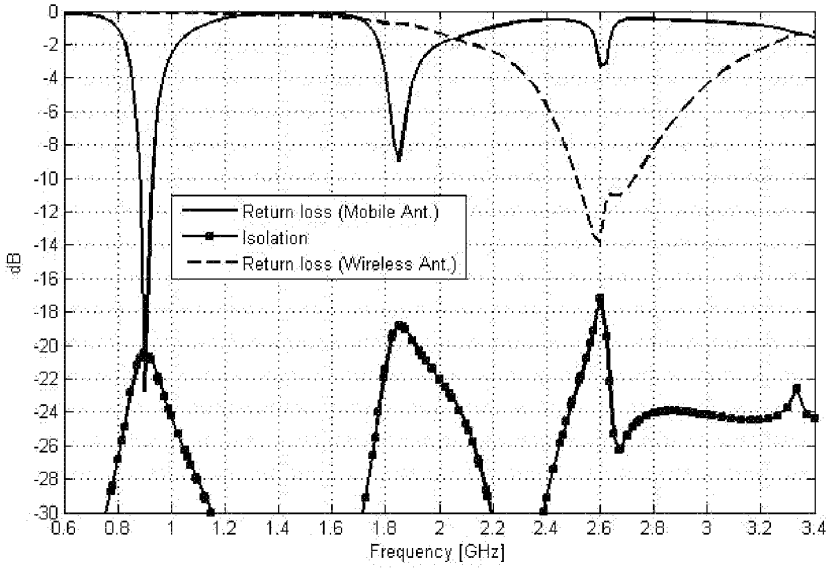


FIG. 3B

(PRIOR ART)

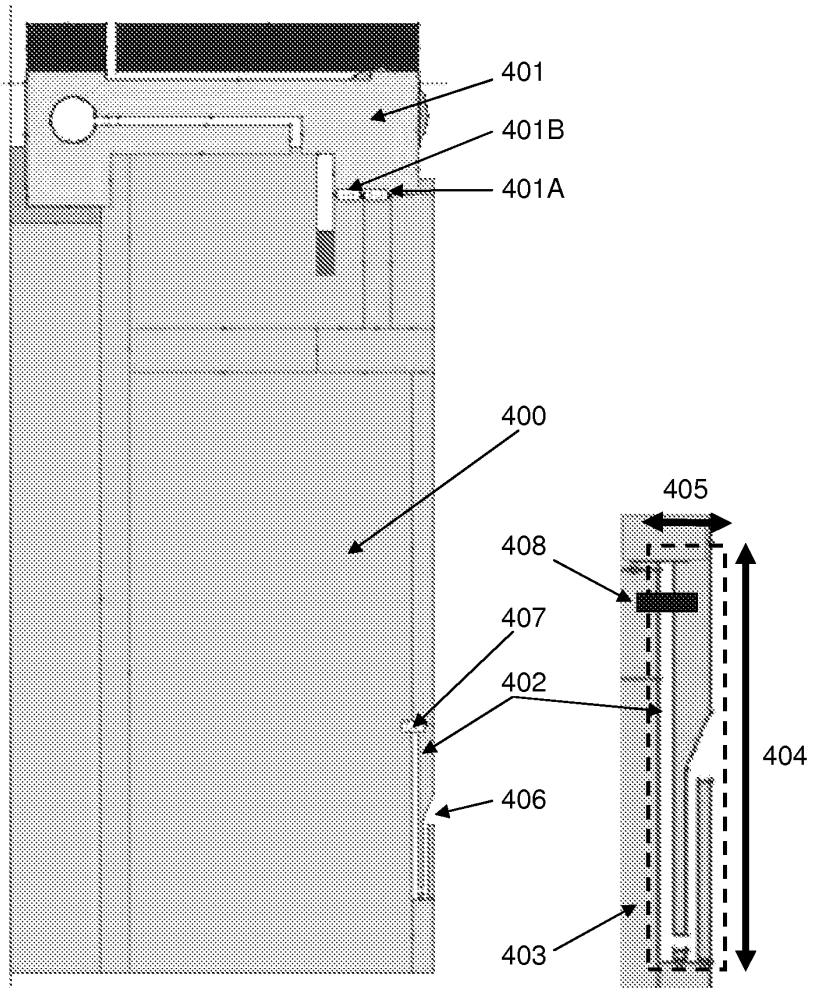


FIG. 4A FIG. 4B

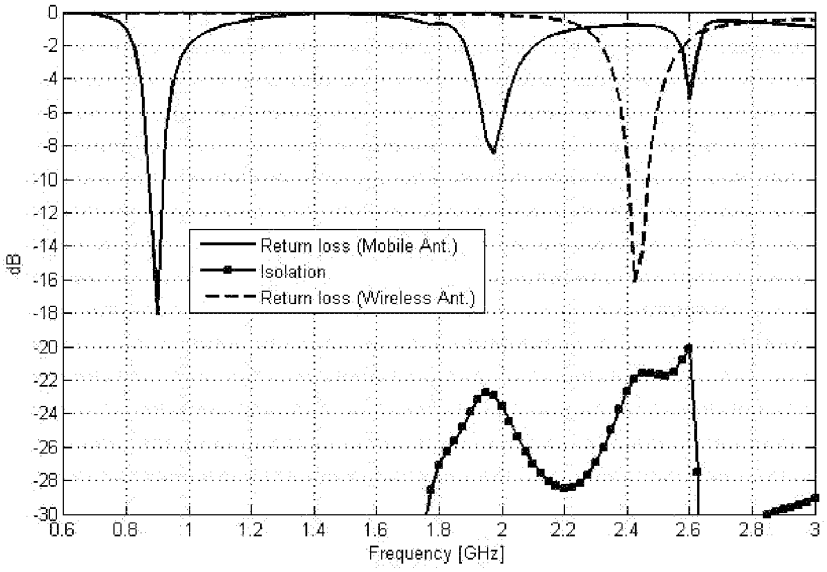

Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)
dB
Frequency [GHz]

FIG. 5A

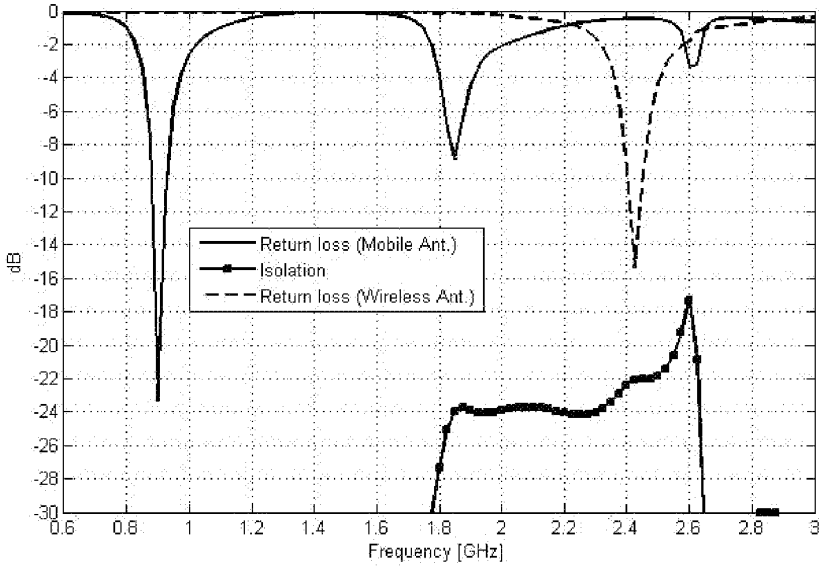

Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)
dB
Frequency [GHz]

FIG. 5B

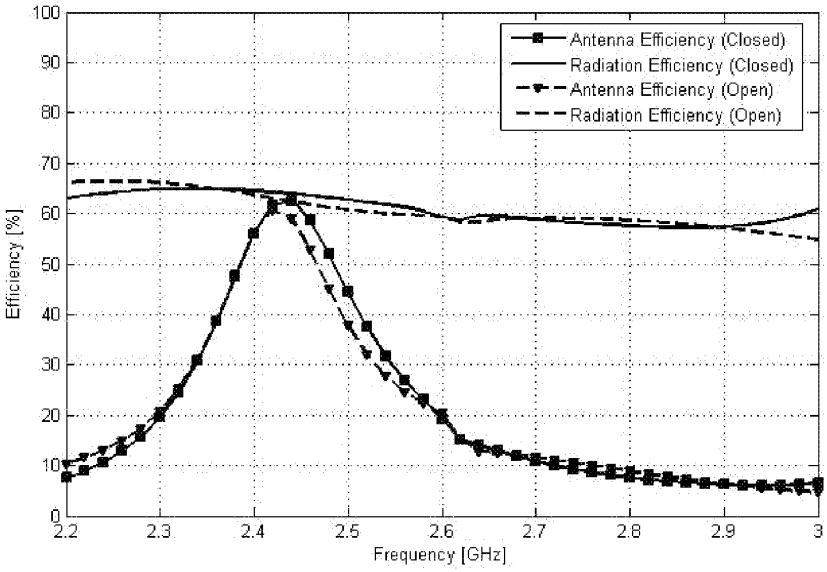

Antenna Efficiency (Closed)
Radiation Efficiency (Closed)
Antenna Efficiency (Open)
Radiation Efficiency (Open)
Efficiency [%]
Frequency [GHz]
100
90
80
70
60
50
40
30
20
10
0
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3

FIG. 6

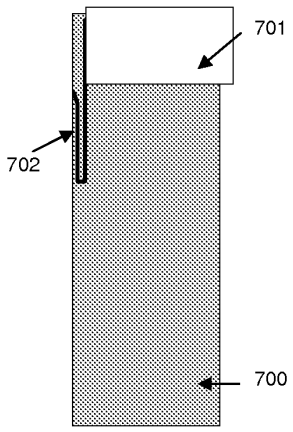


FIG. 7A

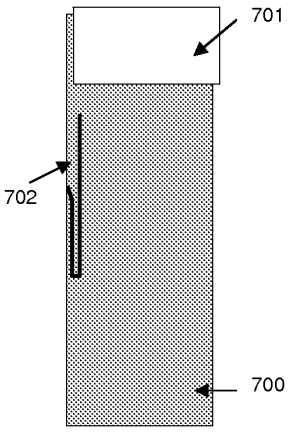


FIG. 7B

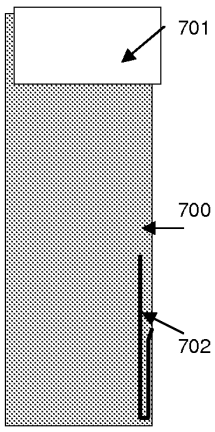


FIG. 7C

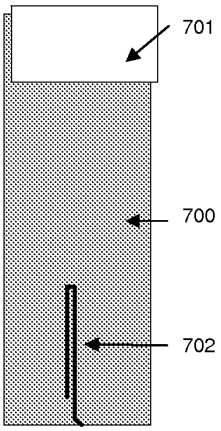


FIG. 7D

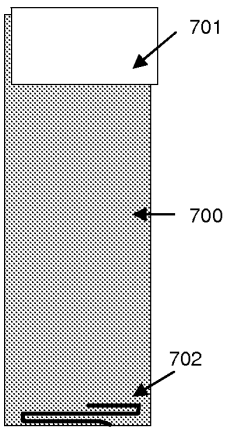


FIG. 7E

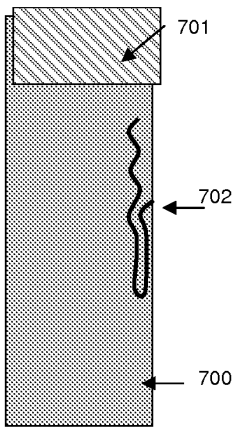


FIG. 7F

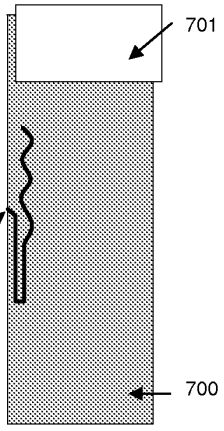


FIG. 7G

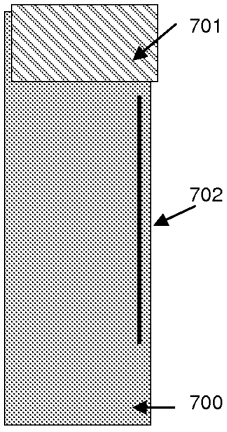


FIG. 7H

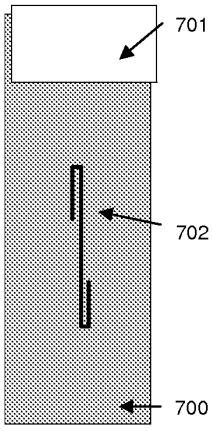


FIG. 7I

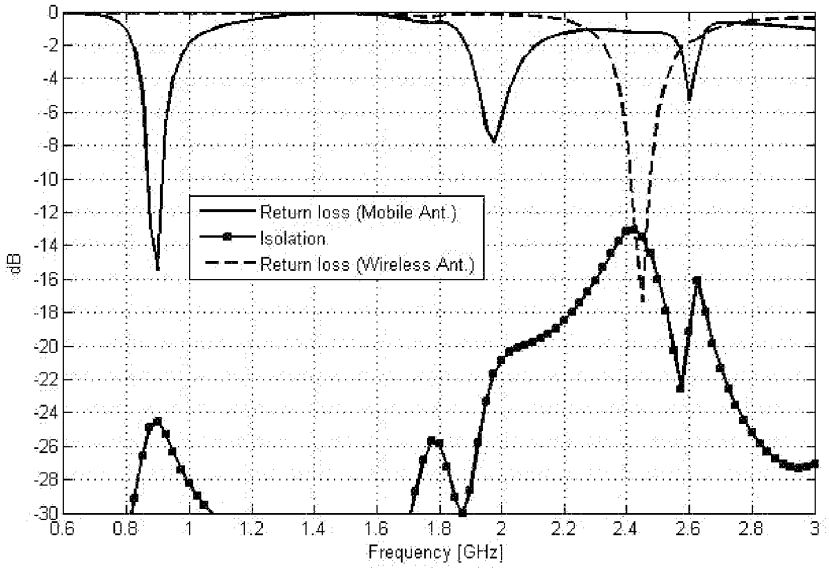

Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)
dB
Frequency [GHz]

FIG. 8A

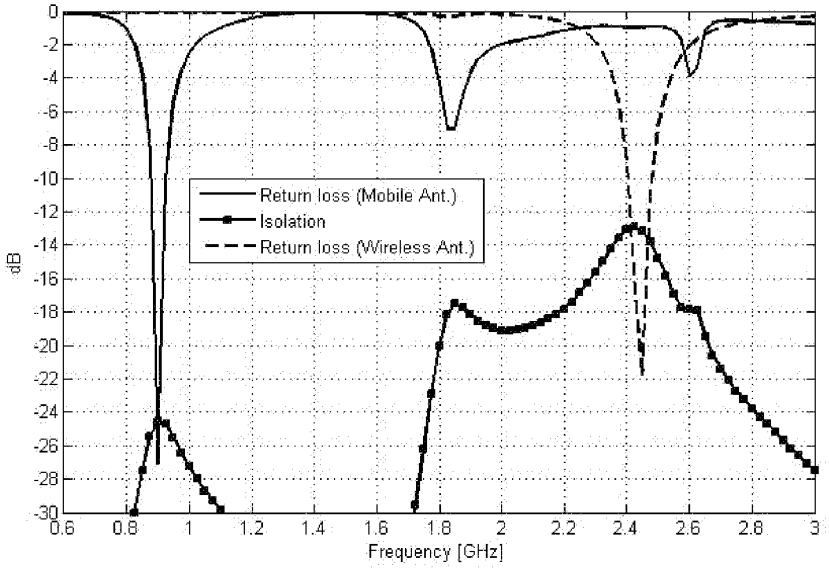

Return loss (Mobile Ant.)
Isolation
Return loss (Wireless Ant.)
dB
Frequency [GHz]

FIG. 8B

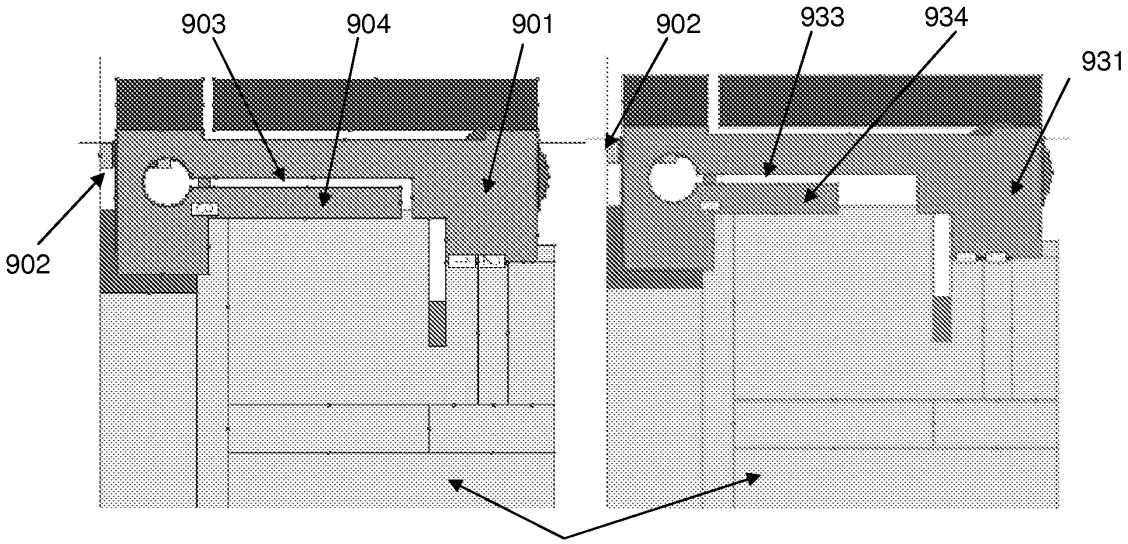


FIG. 9A FIG. 9B

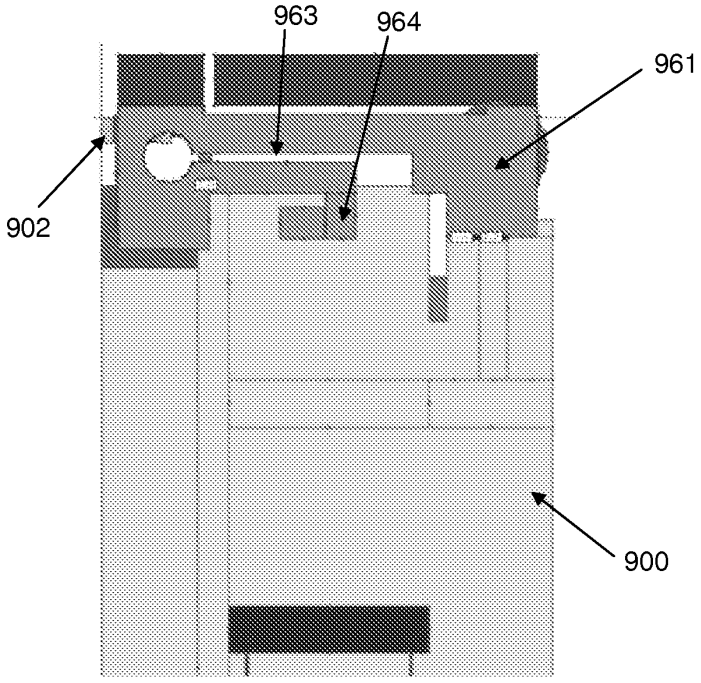


FIG. 9C

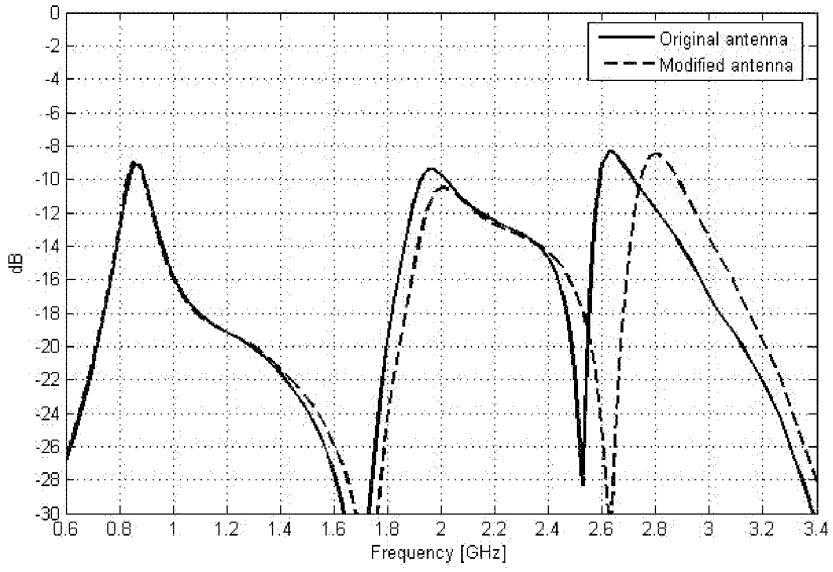

Original antenna
Modified antenna
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 10

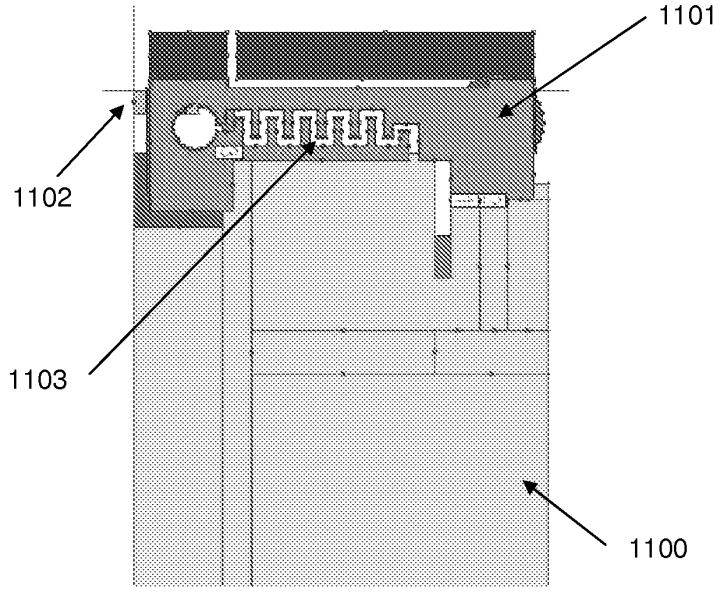


FIG. 11A

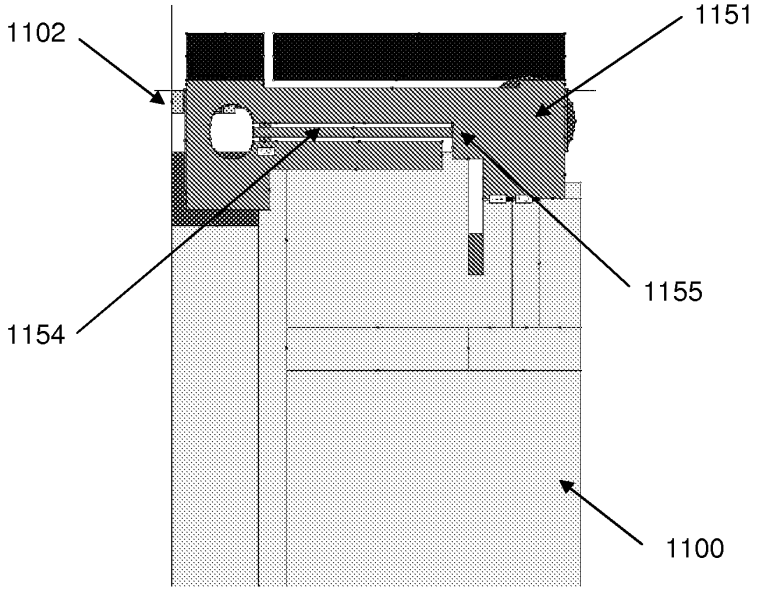


FIG. 11B

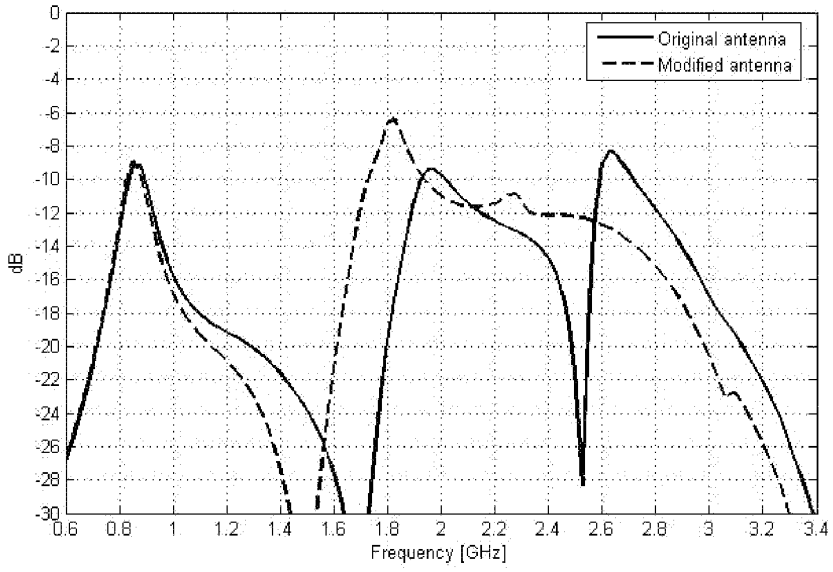

Original antenna
Modified antenna
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 12

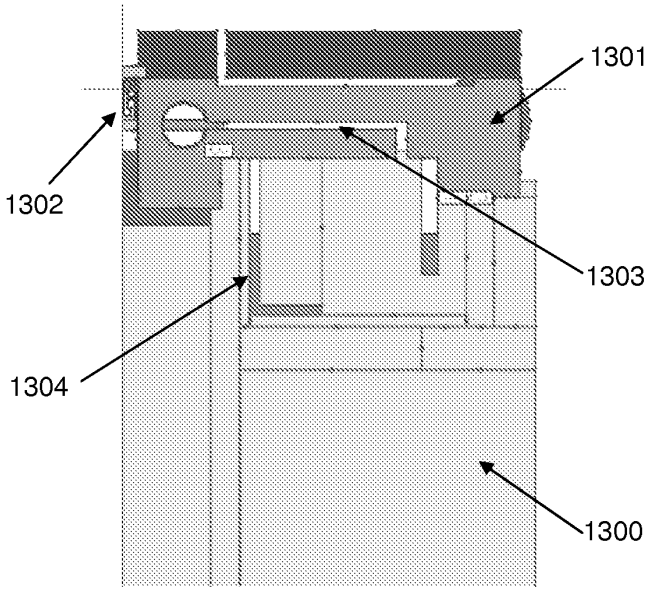


FIG. 13A

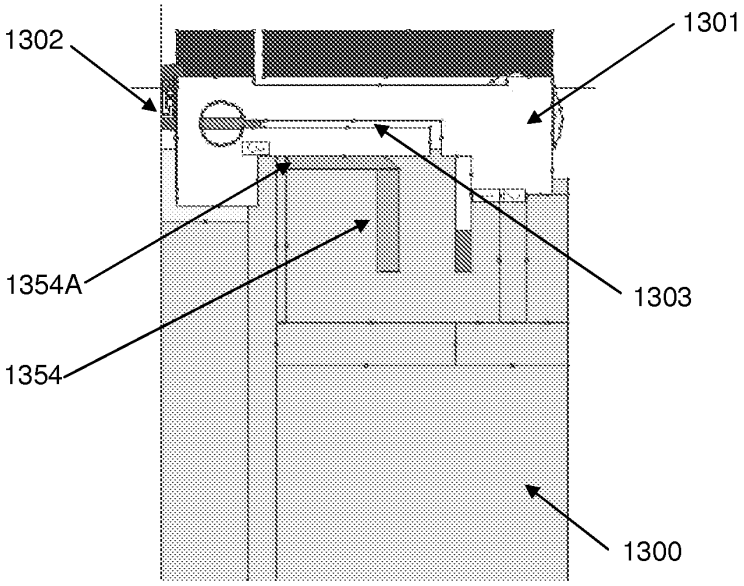


FIG. 13B

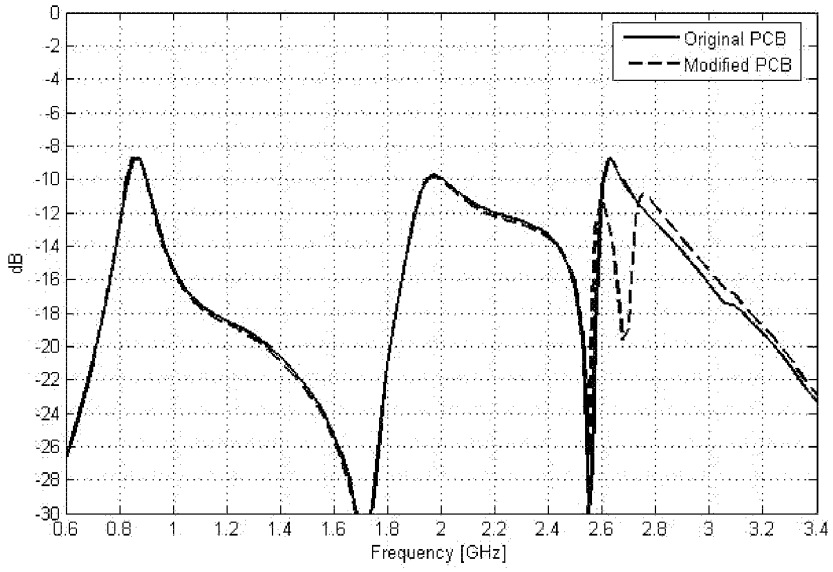

Original PCB
Modified PCB
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 14

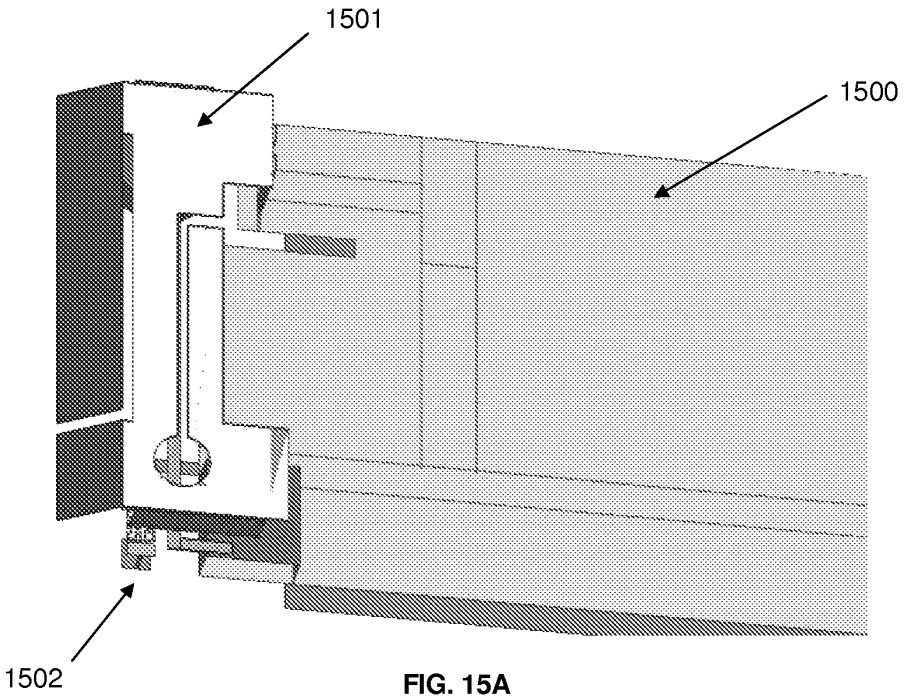


FIG. 15A

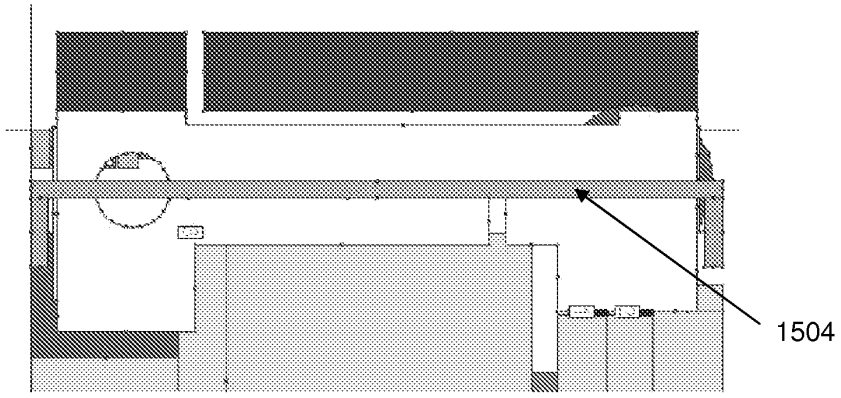


FIG. 15B

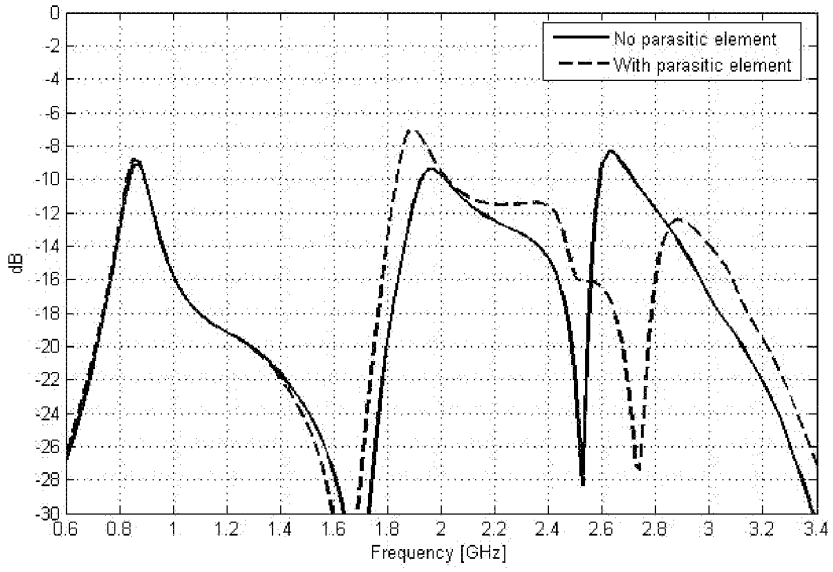

No parasitic element
With parasitic element
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

FIG. 16

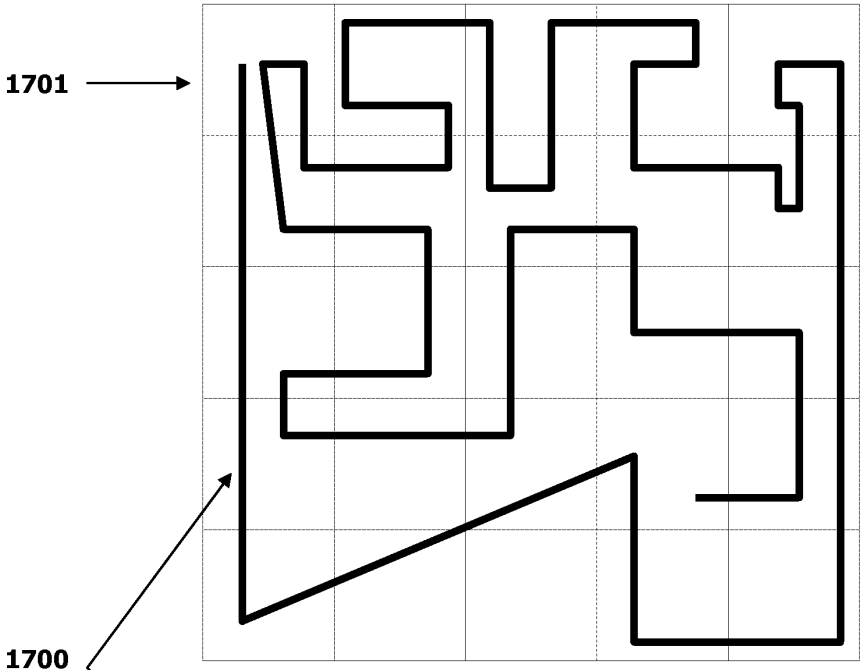


FIG. 17A

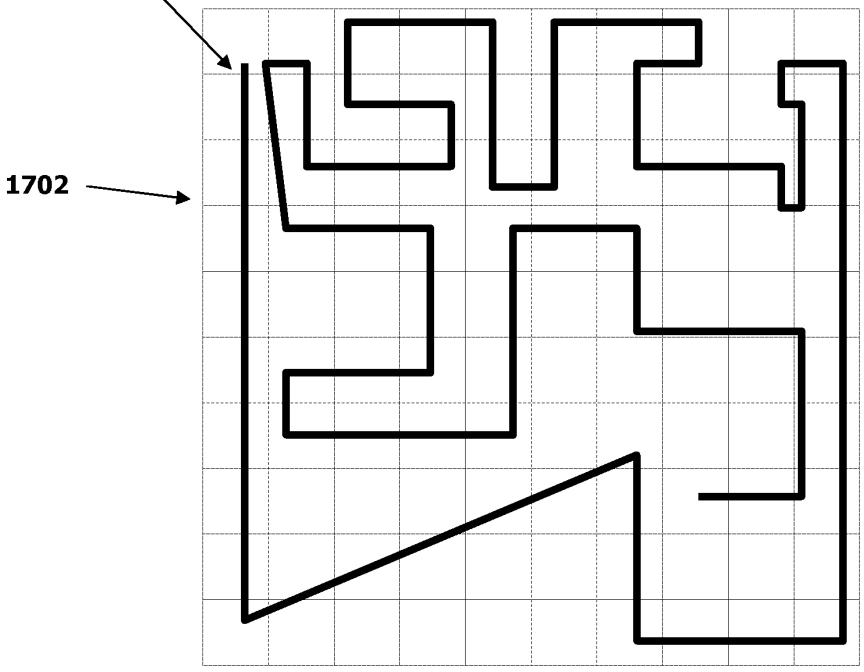


FIG. 17B

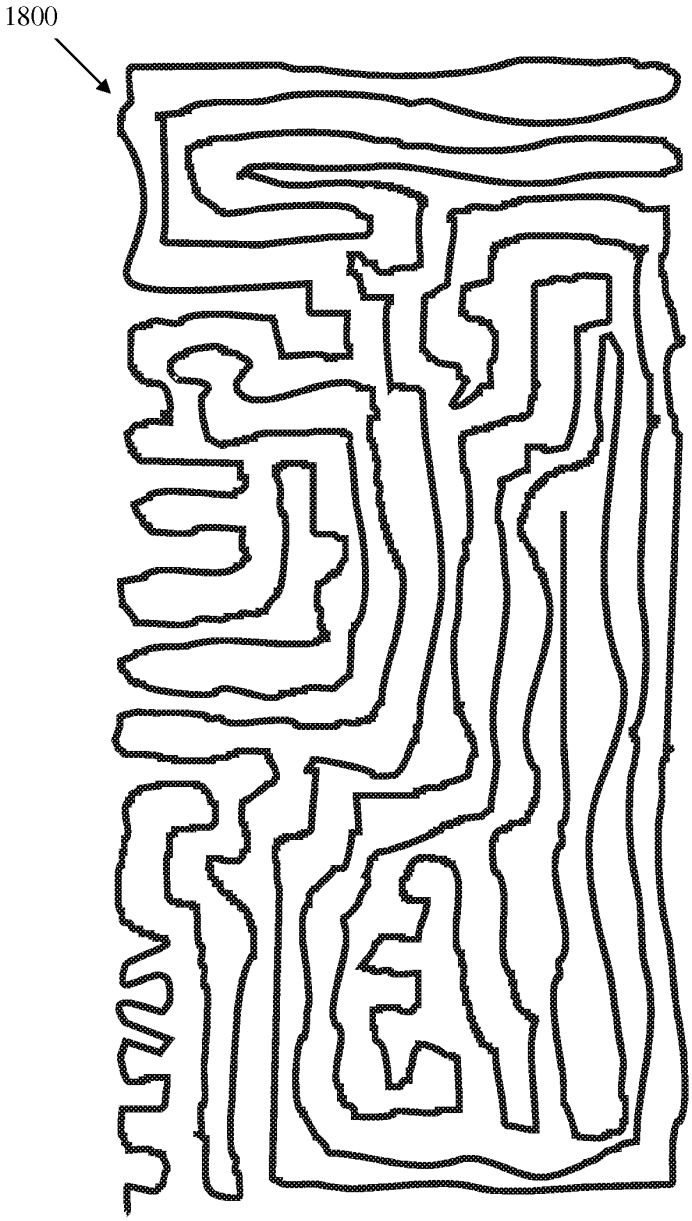


FIG. 18

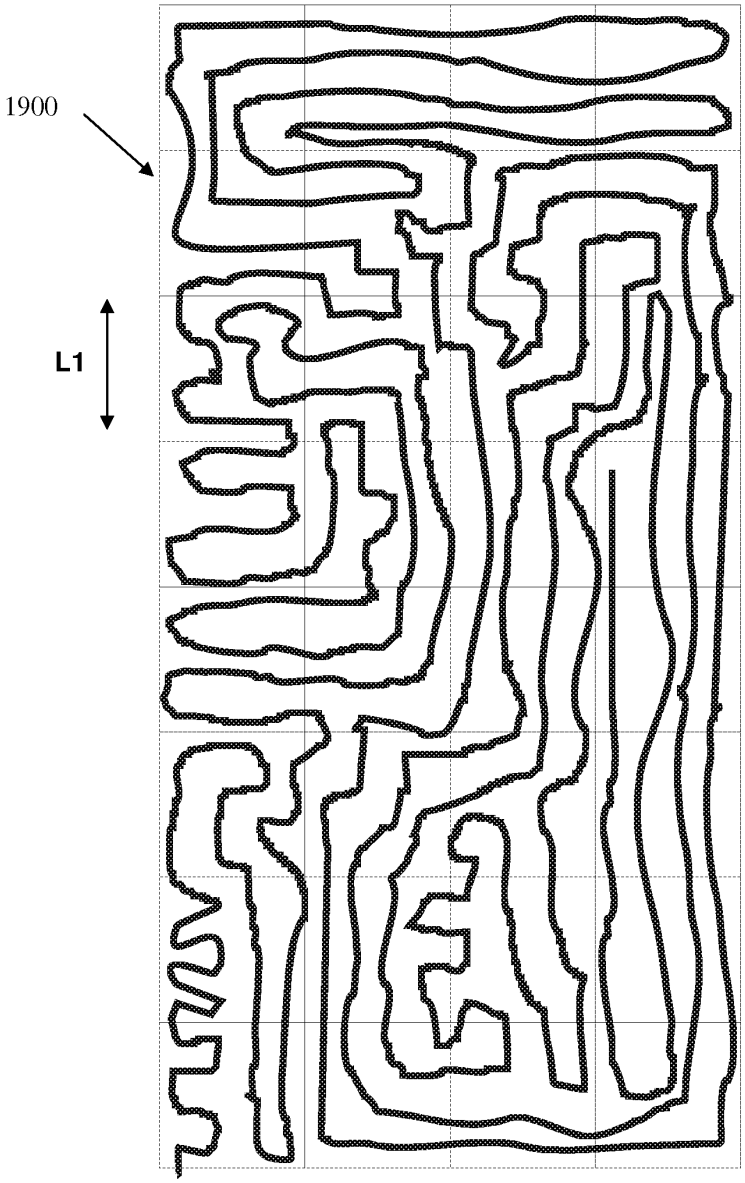


FIG. 19

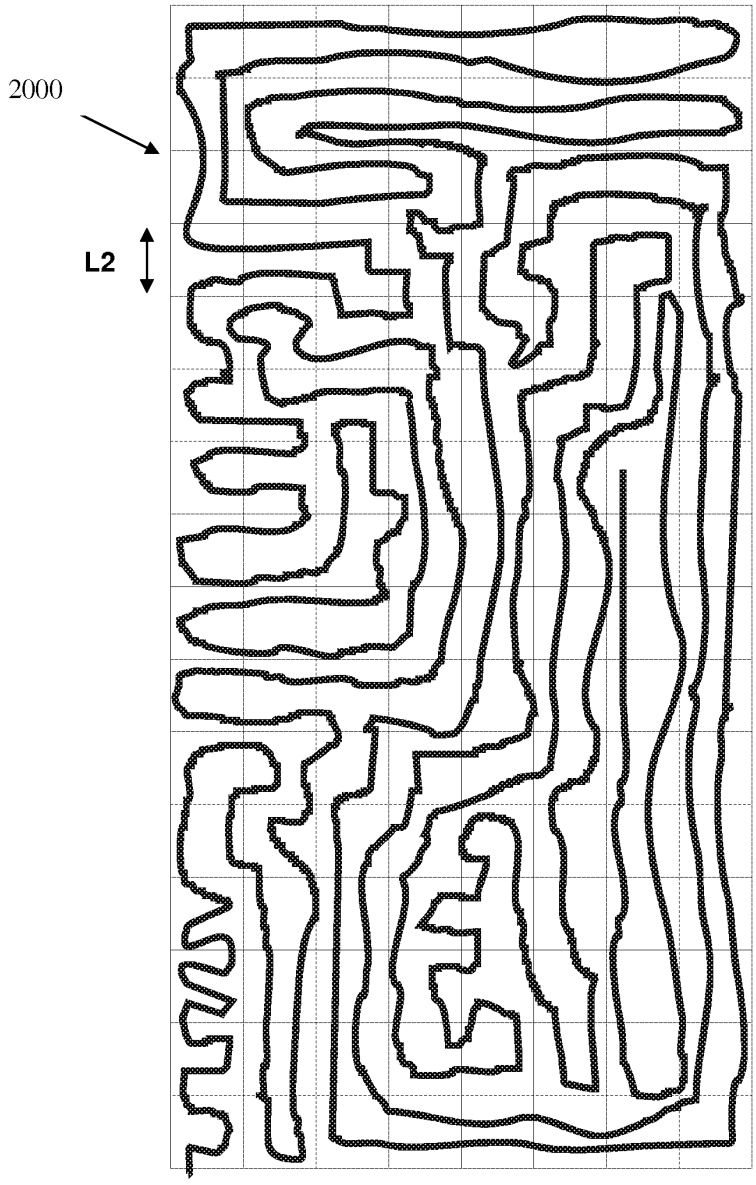


FIG. 20

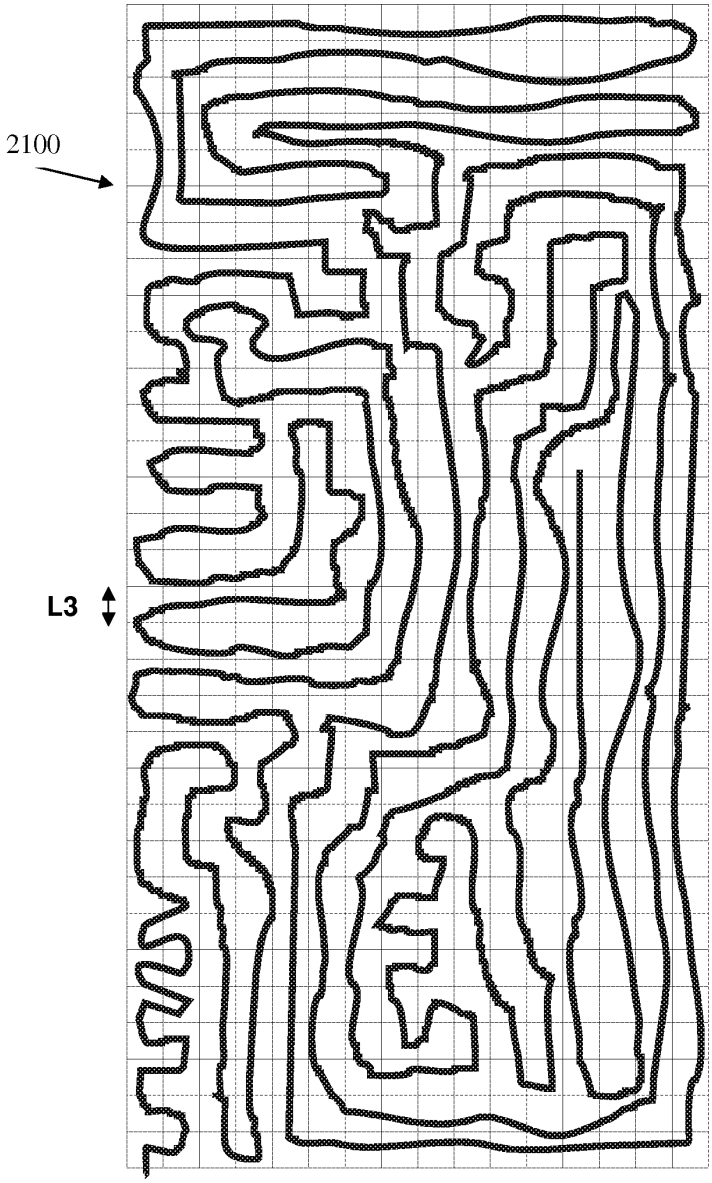


FIG. 21

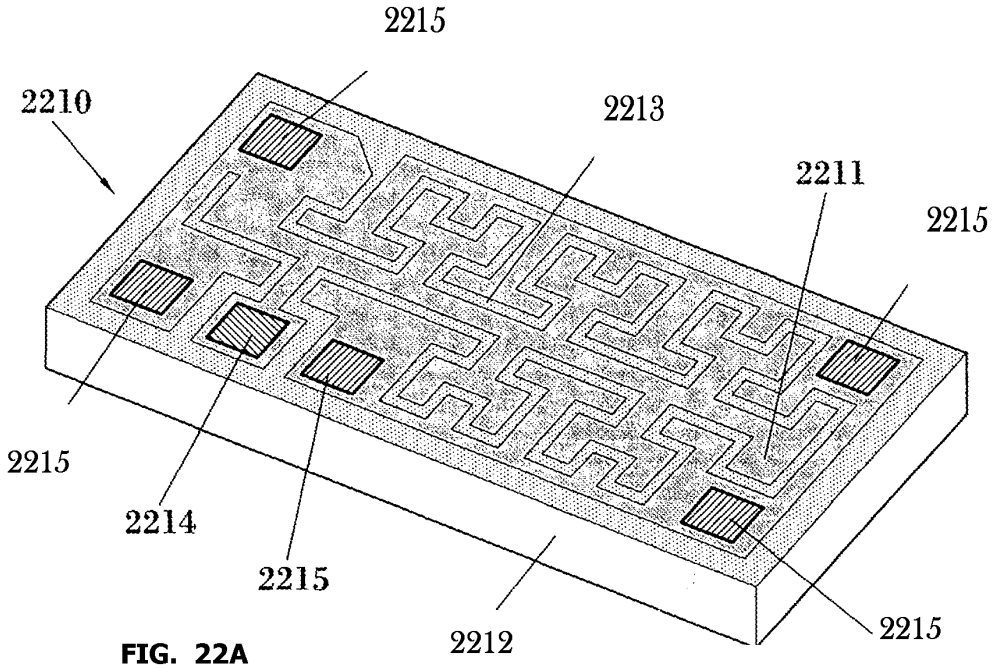


FIG. 22A

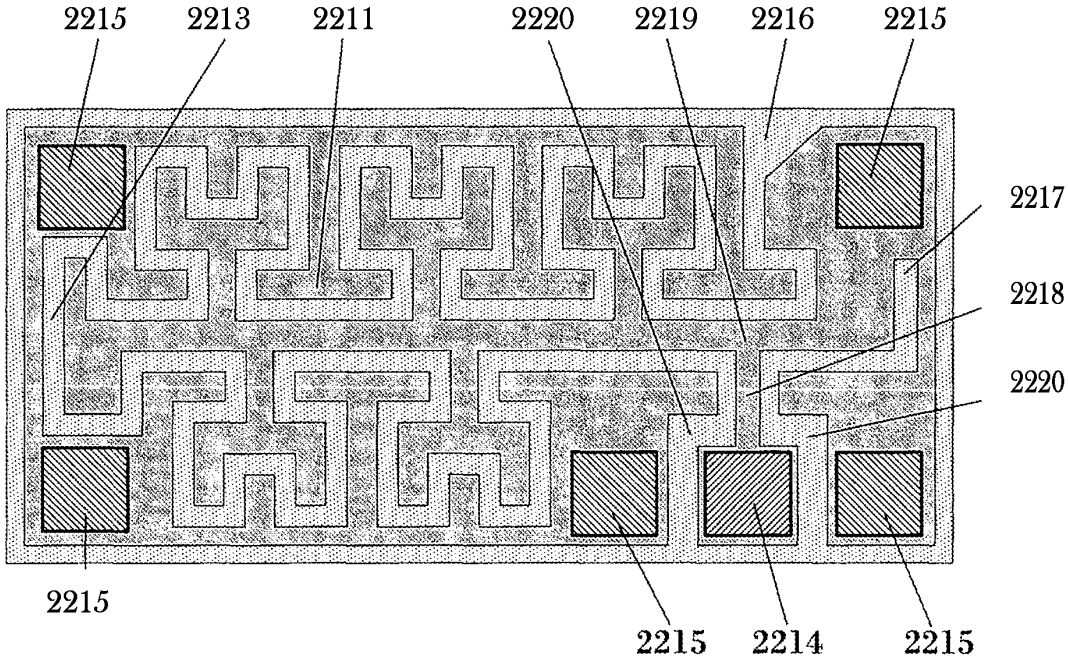


FIG. 22B

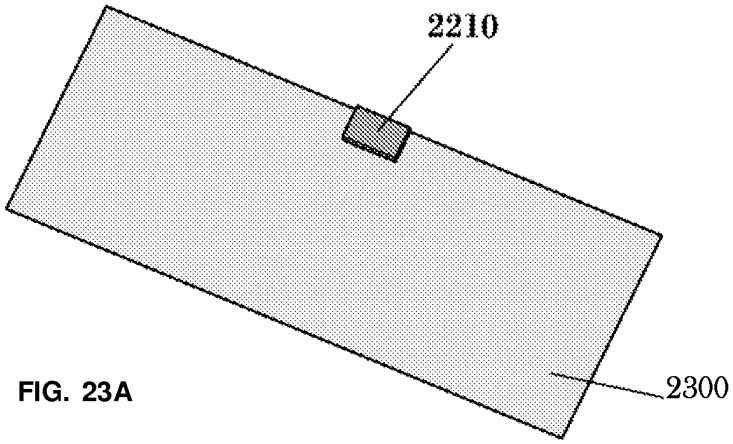


FIG. 23A

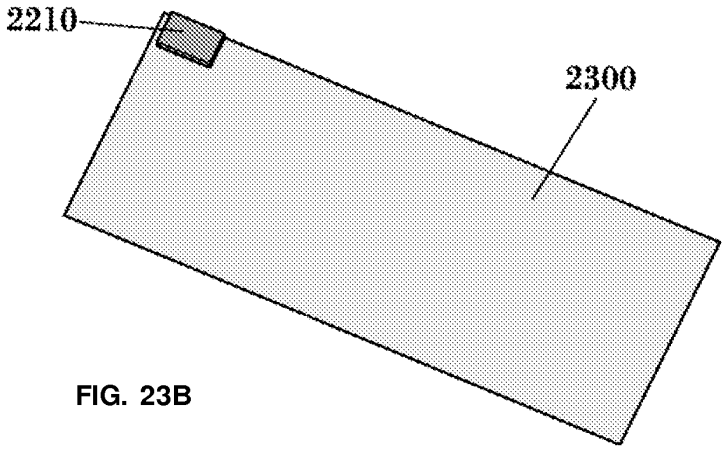


FIG. 23B

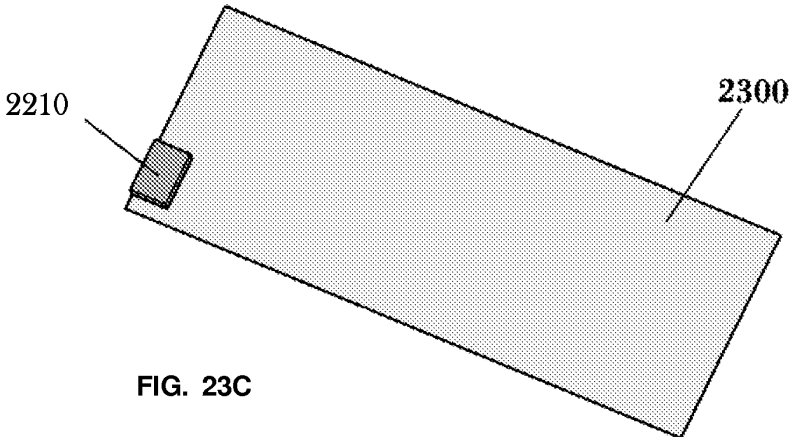


FIG. 23C

DocCode – SCORE

SCORE Placeholder Sheet for IFW Content

Application Number: 13718348 Document Date: 05/22/2013

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

- Drawing

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

To access the documents in the SCORE database, refer to instructions developed by SIRA.

At the time of document entry (noted above):

- Examiners may access SCORE content via the eDAN interface.
- Other USPTO employees can bookmark the current SCORE URL (http://es/ScoreAccessWeb/).
- External customers may access SCORE content via the Public and Private PAIR interfaces.

Form Revision Date: February 8, 2006

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	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/718,348	12/18/2012	2821	1390	47005-P040WUSC2	20	3

CONFIRMATION NO. 8109

UPDATED FILING RECEIPT

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

OC000000061582875

Date Mailed: 05/30/2013

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Josep Mumbru, Barcelona, SPAIN;
Jaume Anguera, Castellon, SPAIN;
Jordi Soler, Mataro, SPAIN;
Carles Puente, Sant Cugat del Valles, SPAIN;

Applicant(s)

Fractus, S.A., Sant Cugat del Valles, SPAIN

Assignment For Published Patent Application

Fractus, S.A., Sant Cugat del Valles, SPAIN

Power of Attorney: The patent practitioners associated with Customer Number 61060

Domestic Priority data as claimed by applicant

This application is a CON of 13/341,051 12/30/2011 PAT 8362960
which is a CON of 11/988,888 09/30/2008 PAT 8115686
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

Request to Retrieve - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to**

Retrieve Electronic Priority Application(s) (PTO/SB/38 or its equivalent). Consequently, the USPTO will attempt to electronically retrieve these priority documents.

If Required, Foreign Filing License Granted: 01/18/2013

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/718,348**

Projected Publication Date: 09/05/2013

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

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific

countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

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 U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop

technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/718,348

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	280
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	600
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720
TOTAL CLAIMS (37 CFR 1.16(i))	20 minus 20 =	*			OR	x 80 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*				x 420 =	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	1600

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($)	ADDITIONAL FEE($)	OR	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.

Europäisches Patentamt
GD1

European Patent Office
DG1

Office européen des brevets
DG1

Bescheinigung

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

Certificate

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:

Anmelder/Applicant(s)/Demandeur(s):

Fractus, S.A.
Alcalde Barnils, 64-68,
Edificio Testa - mod. C3,
Parque Empresarial San Joan Despi
08190 San Cugat Del Valles (Barcelona)/ES

Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

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.

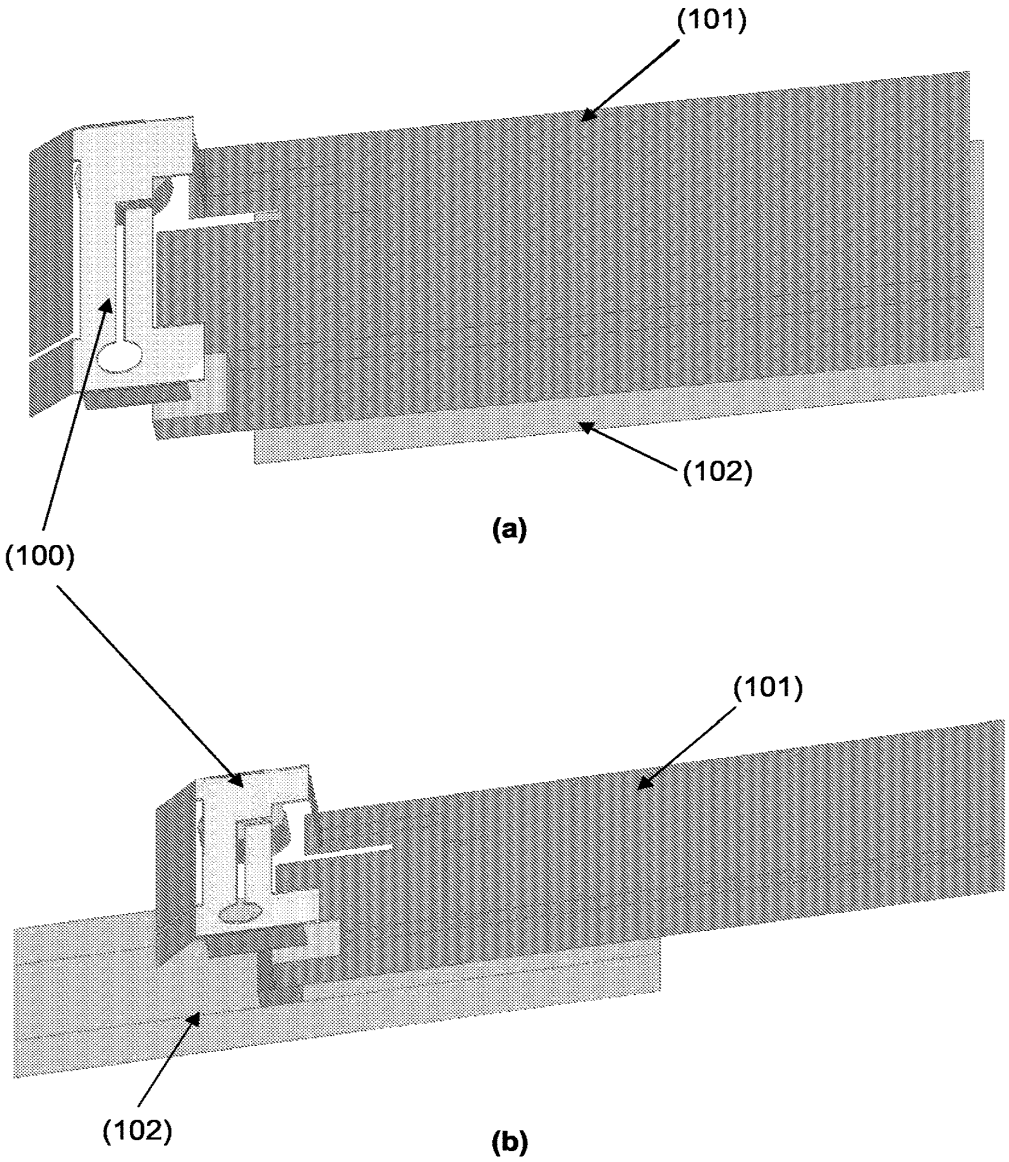


Fig. 1 (PRIOR ART)

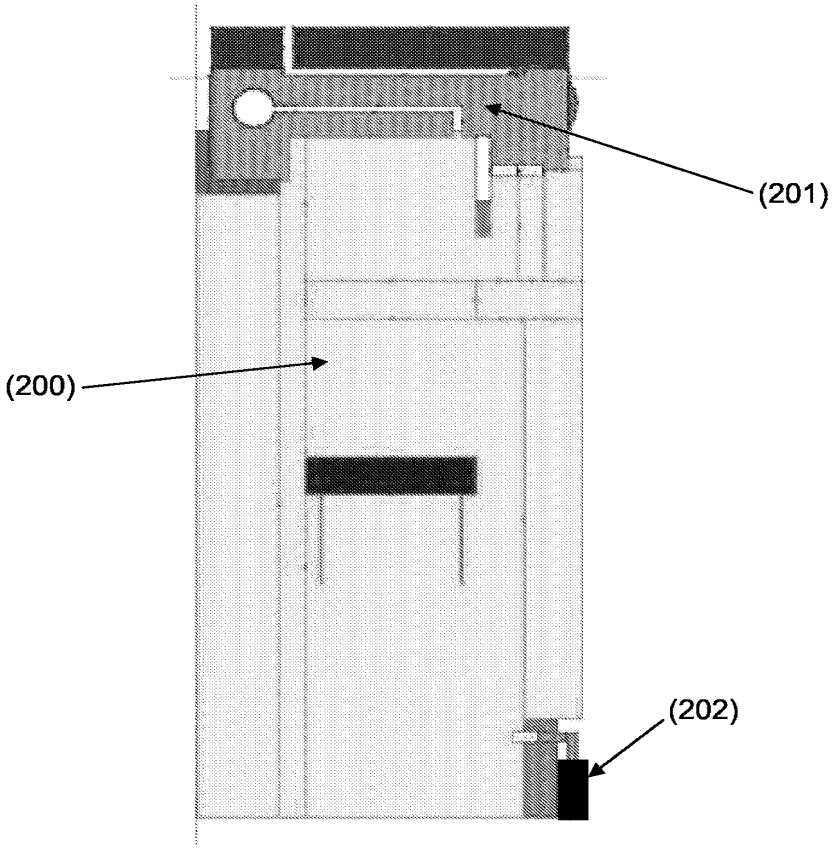
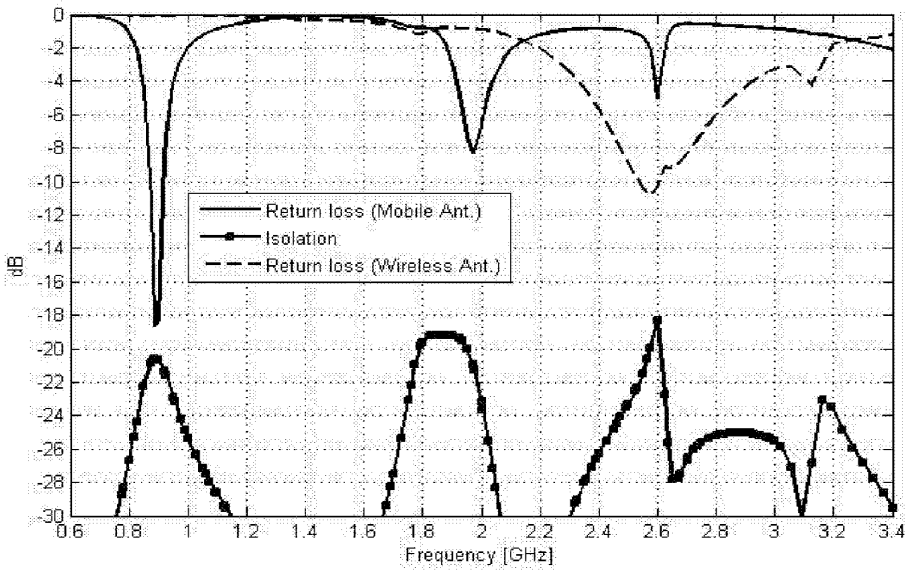
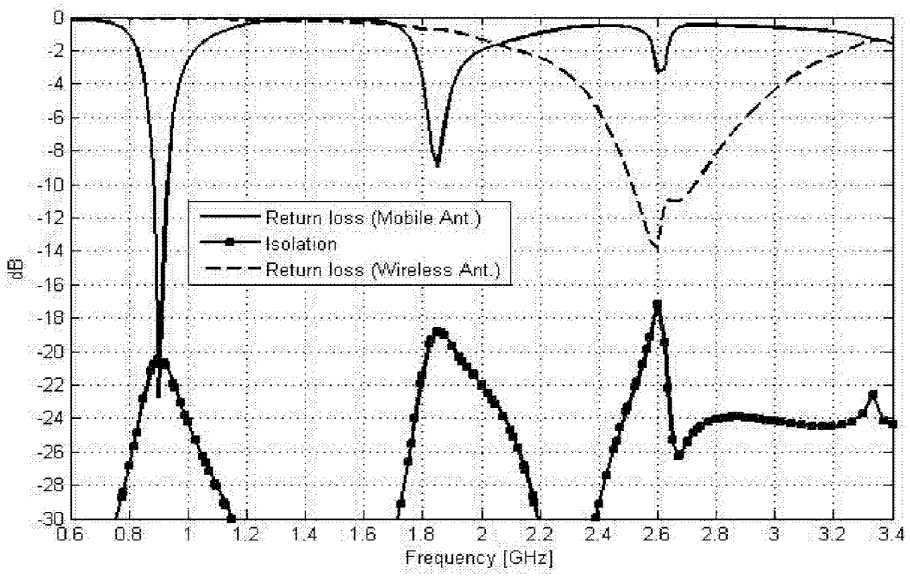


Fig. 2 (PRIOR ART)



(a)



(b)

Fig. 3 (PRIOR ART)

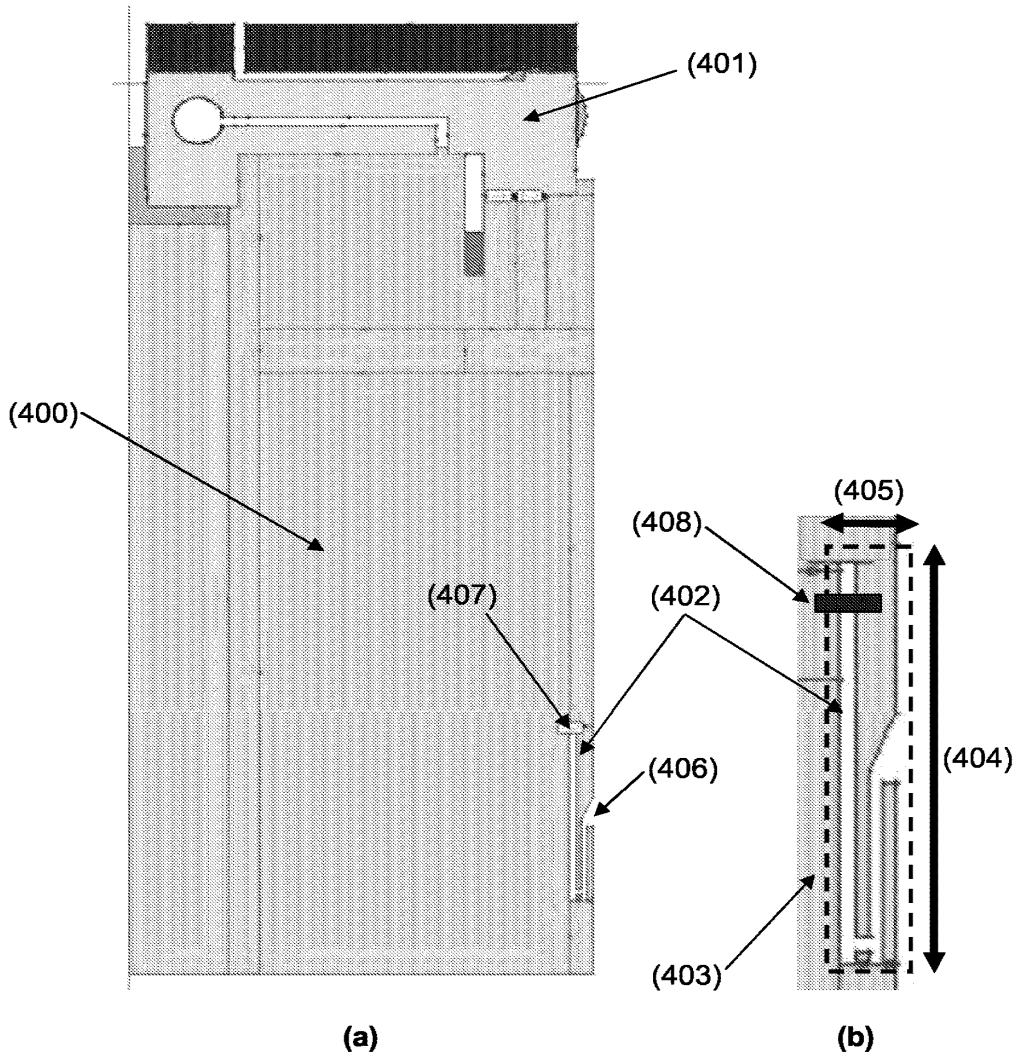
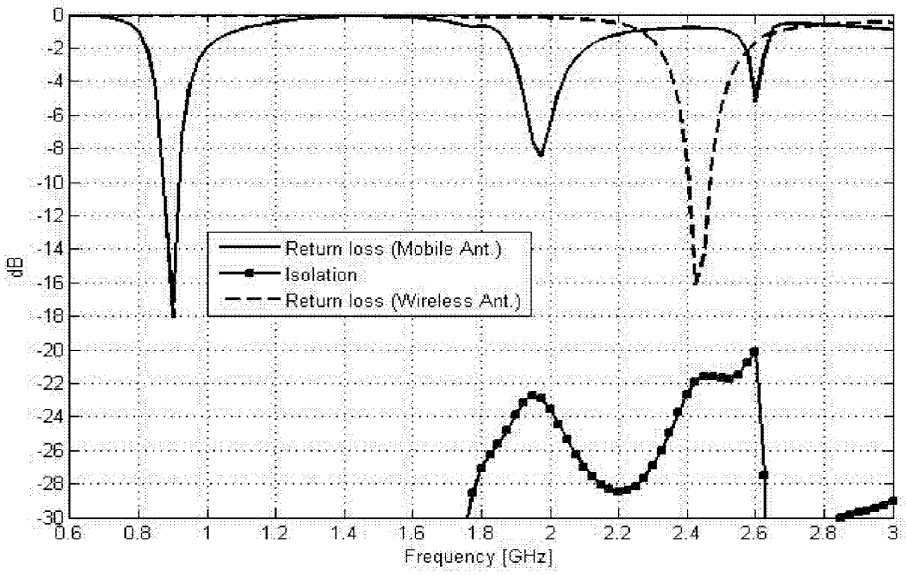
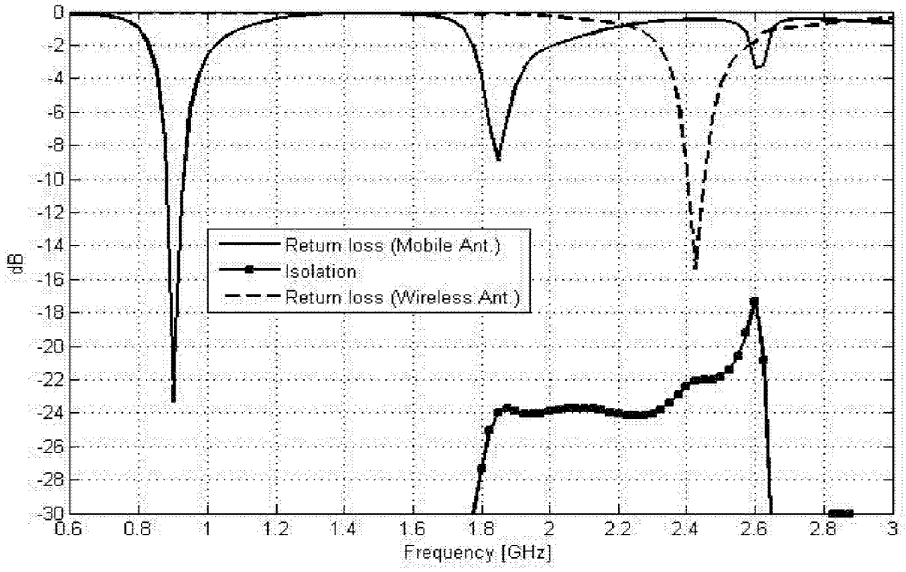


Fig. 4


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. 5

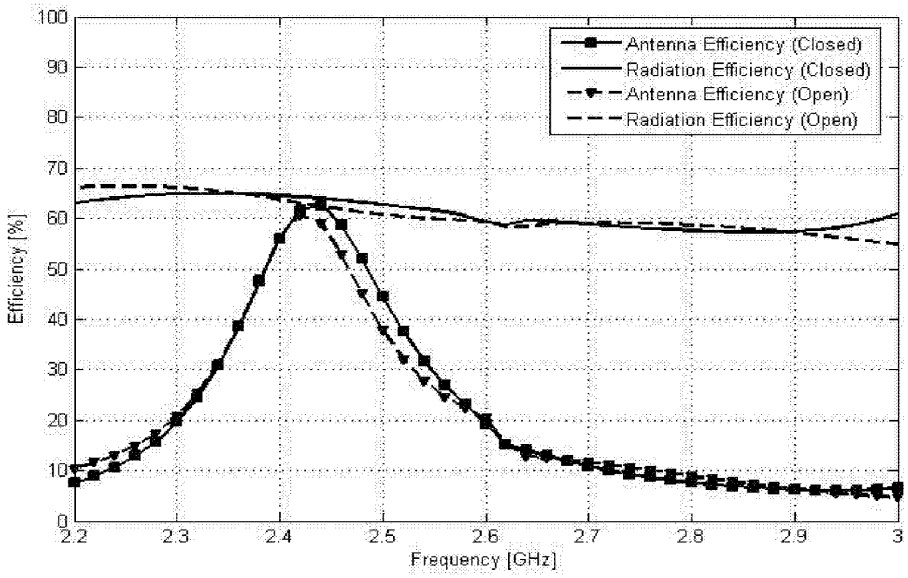

Antenna Efficiency (Closed)
Radiation Efficiency (Closed)
Antenna Efficiency (Open)
Radiation Efficiency (Open)
Efficiency [%]
Frequency [GHz]
100
90
80
70
60
50
40
30
20
10
0
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3

Fig. 6

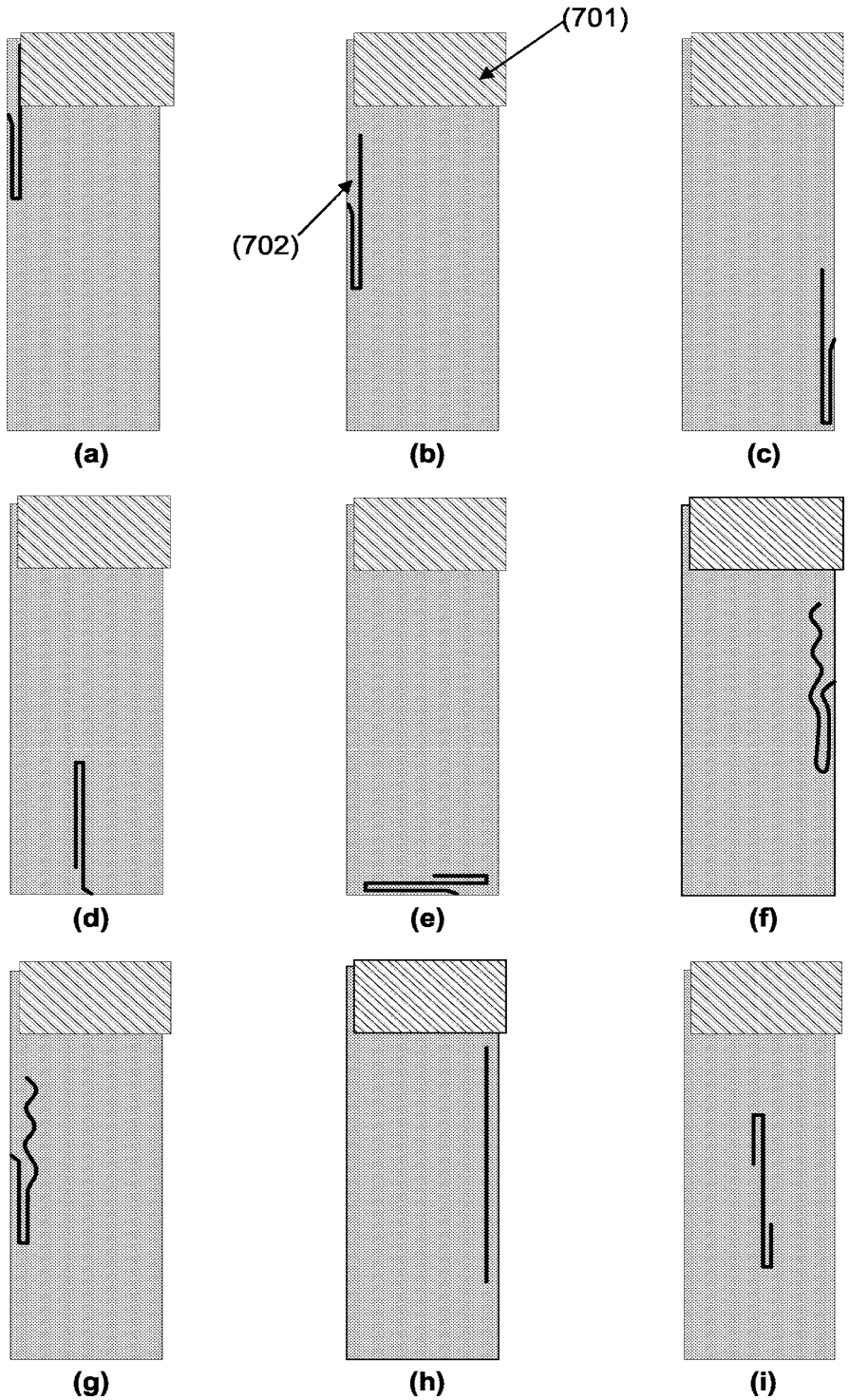
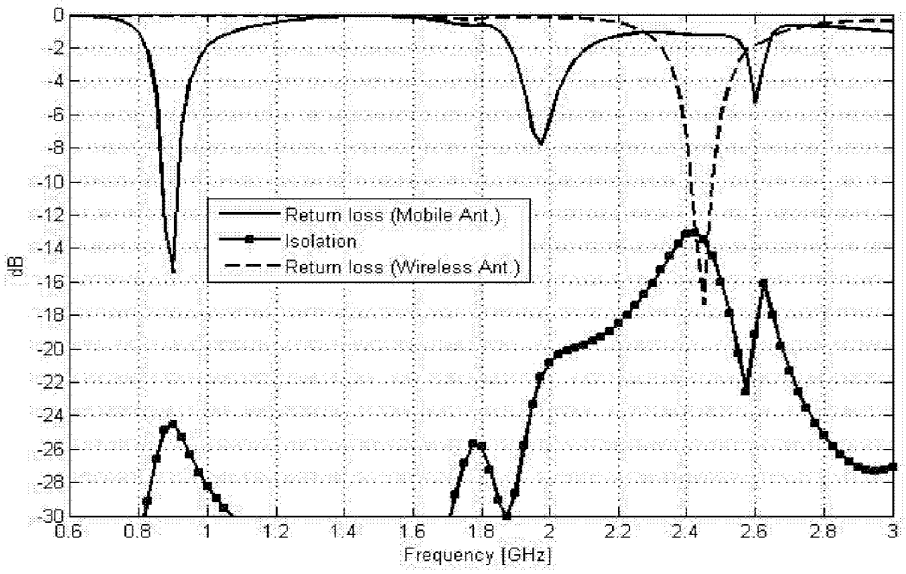
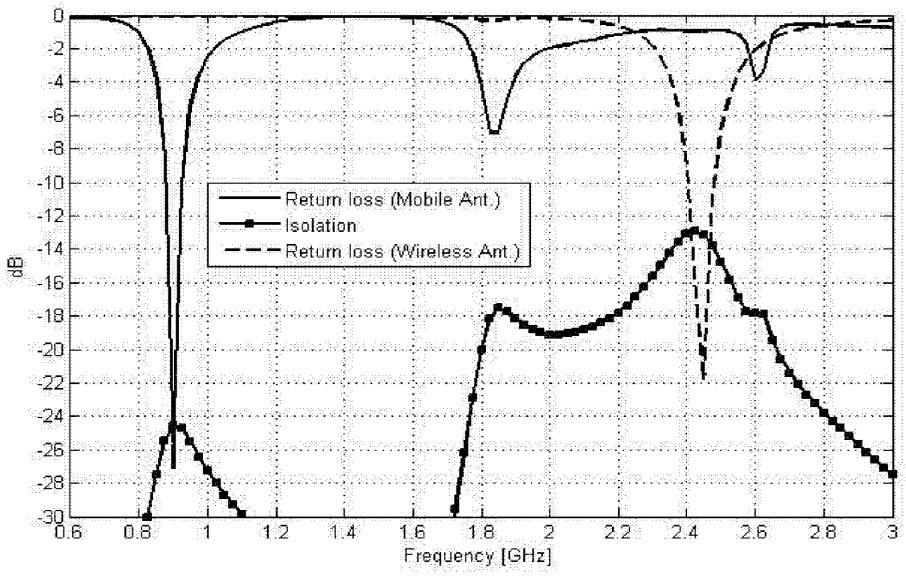


Fig. 7


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

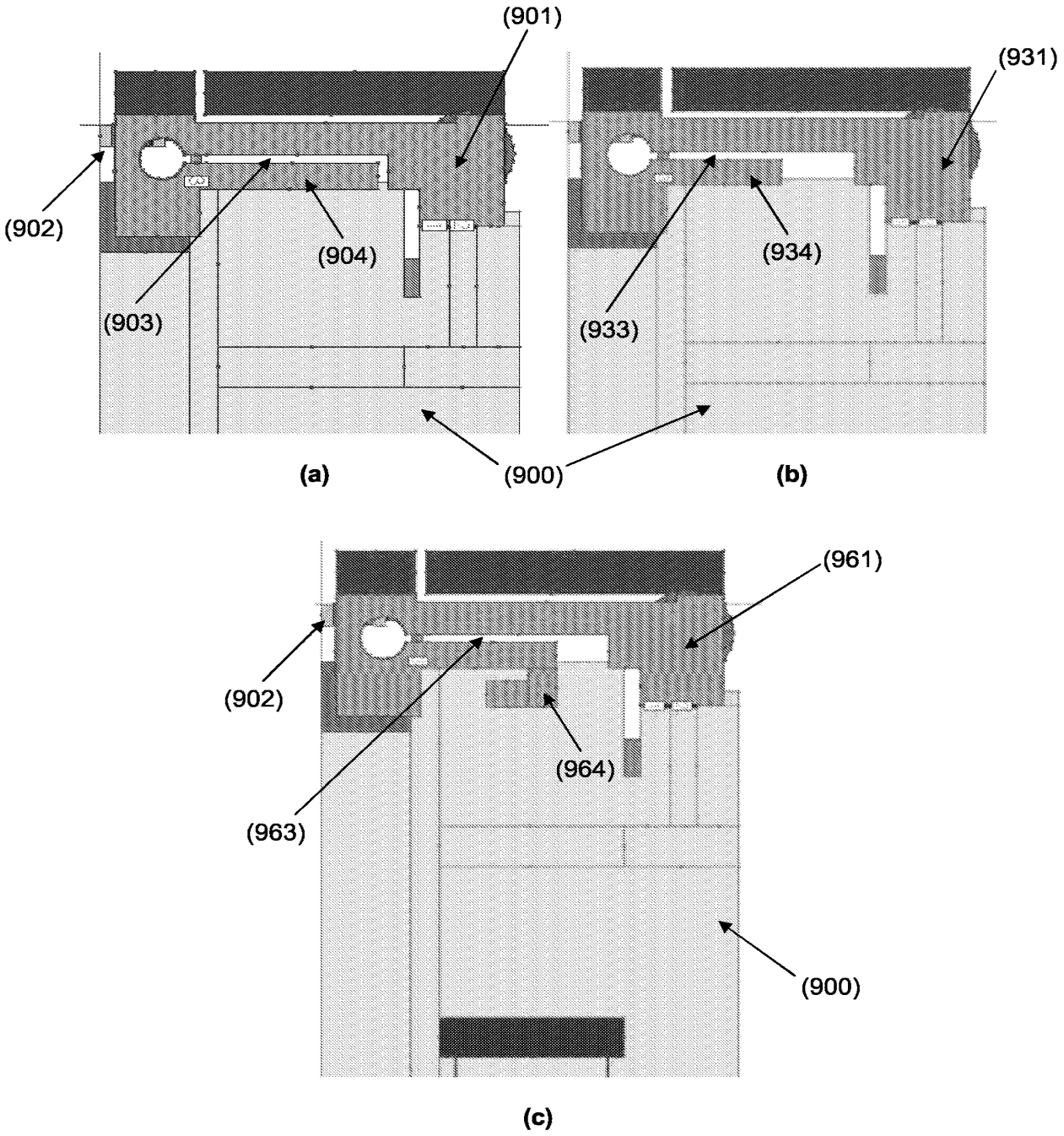


Fig. 9

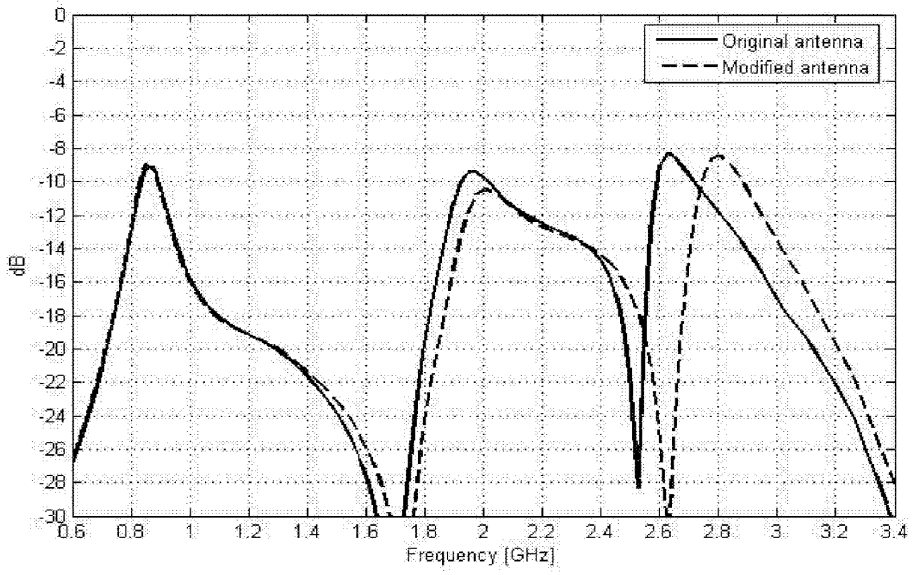
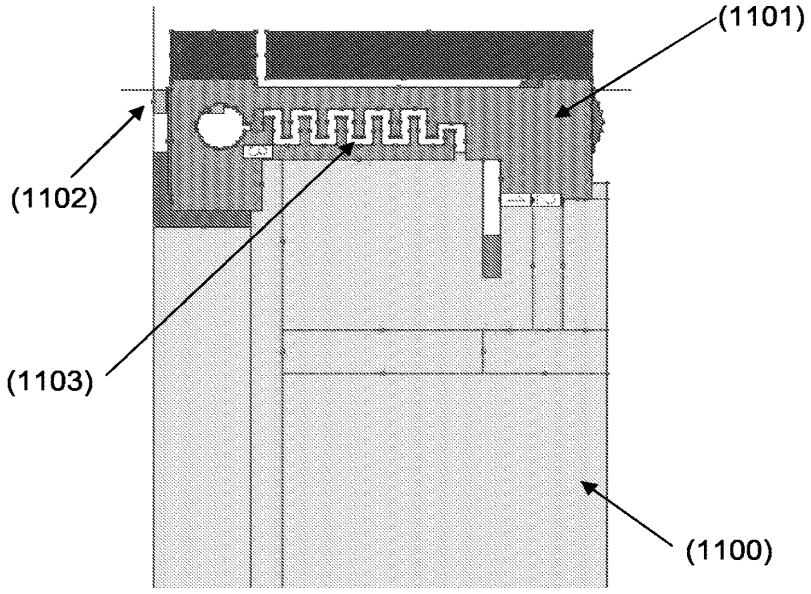
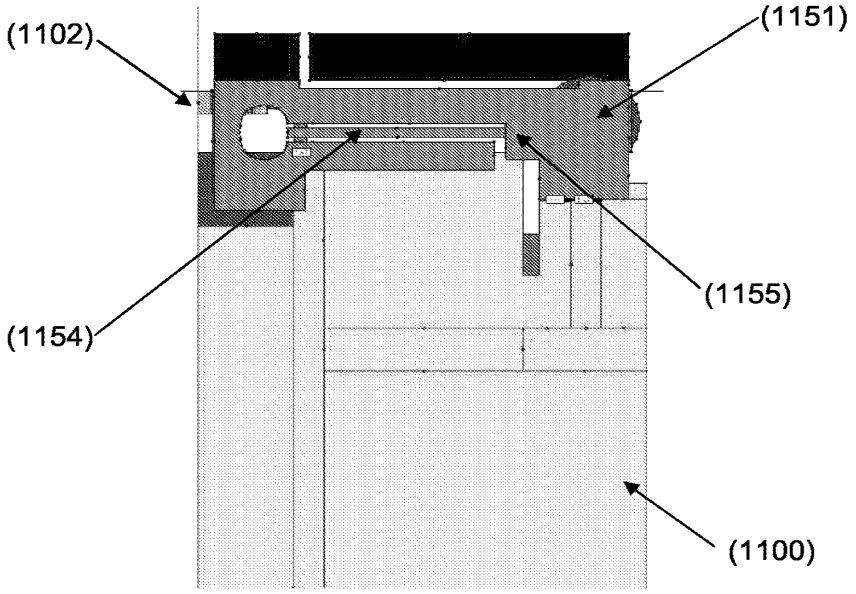

Original antenna
Modified antenna
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

Fig. 10



(a)



(b)

Fig. 11

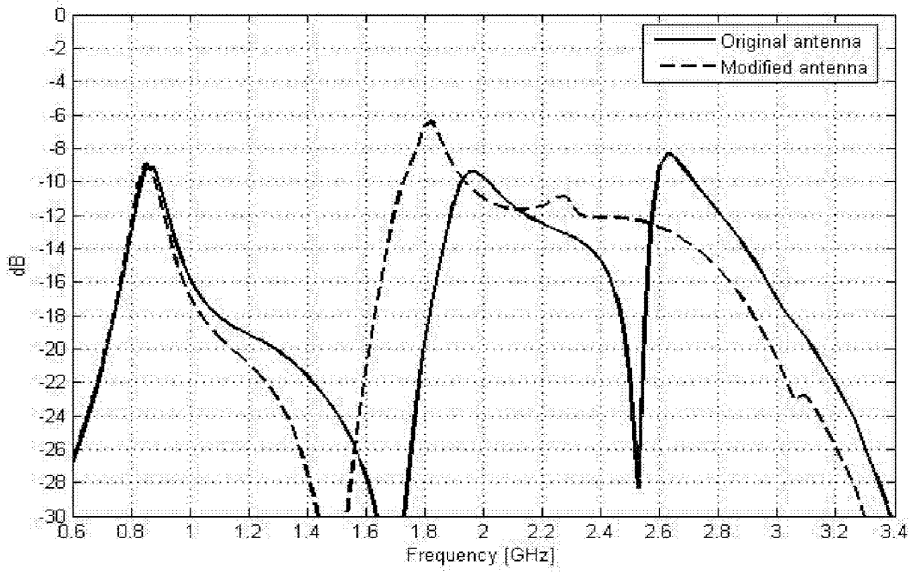
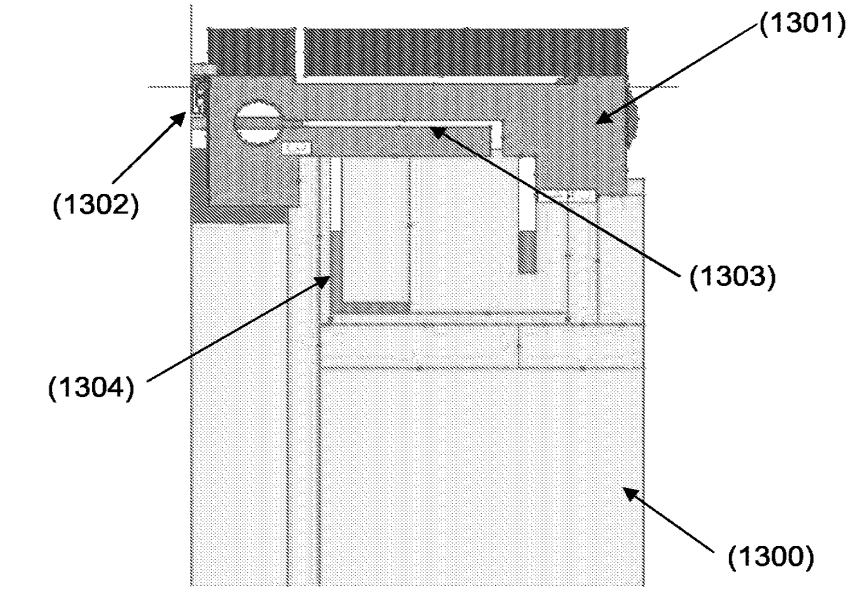
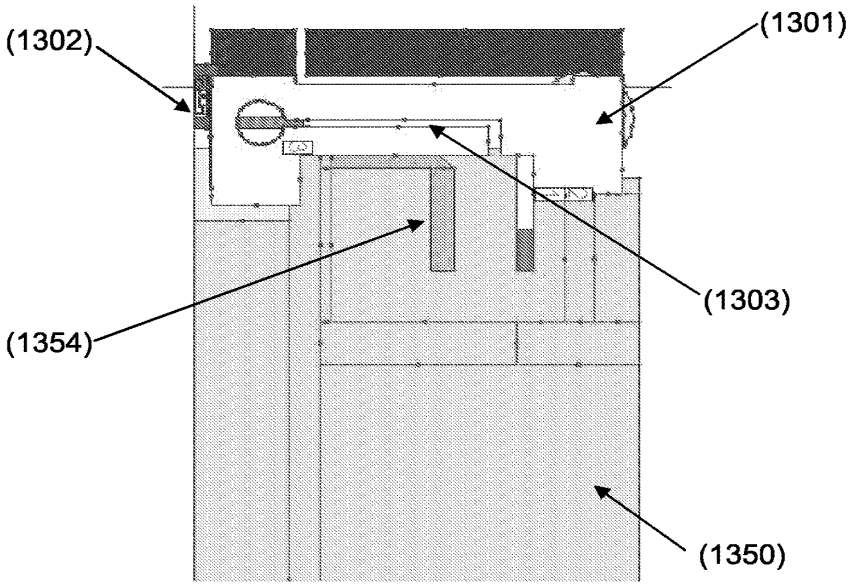

Original antenna
Modified antenna
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

Fig. 12



(a)



(b)

Fig. 13

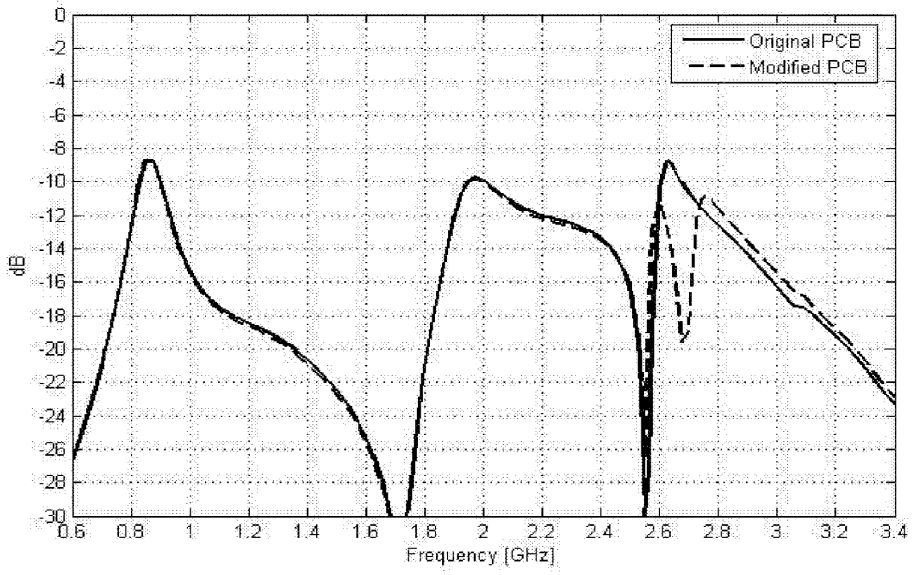
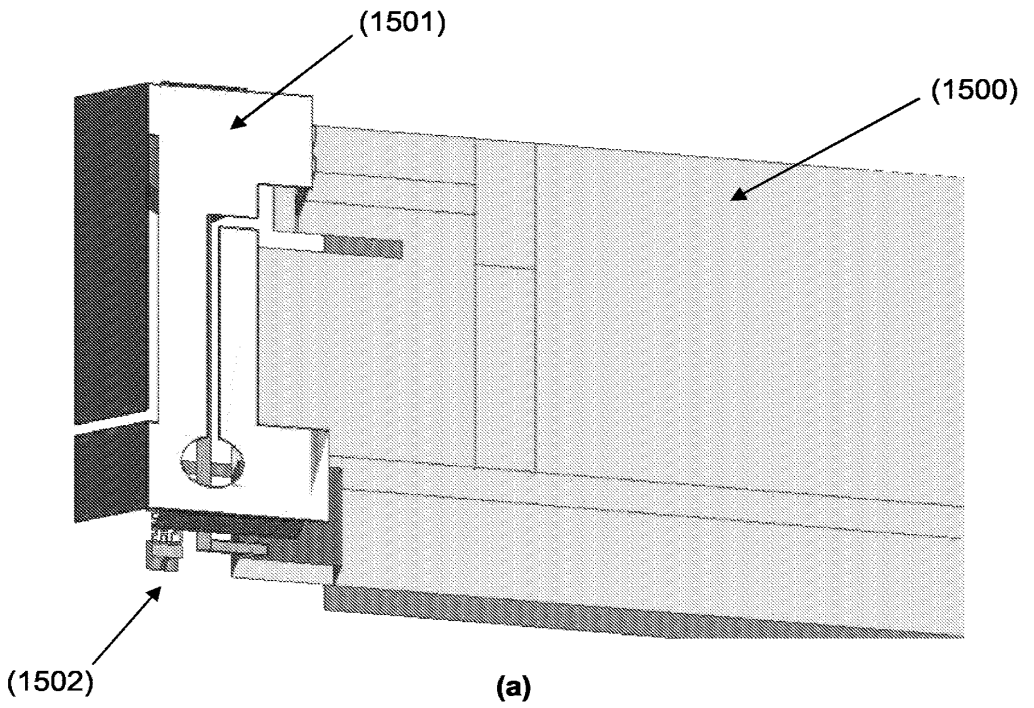
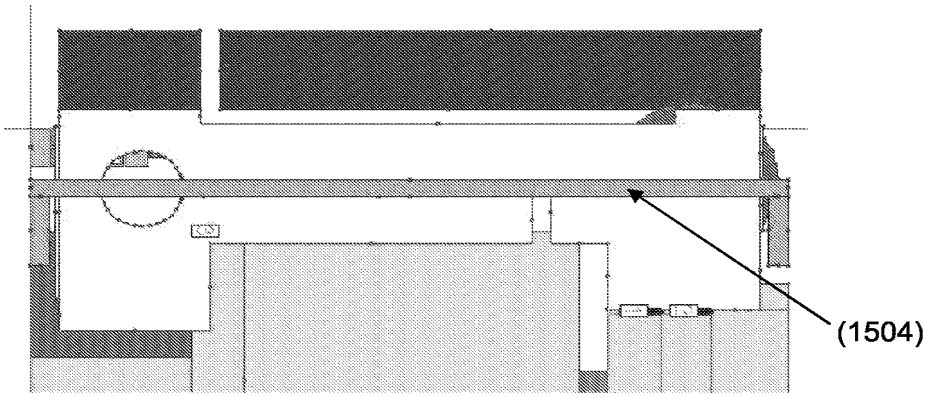

Original PCB
Modified PCB
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

Fig. 14



(a)



(b)

Fig. 15

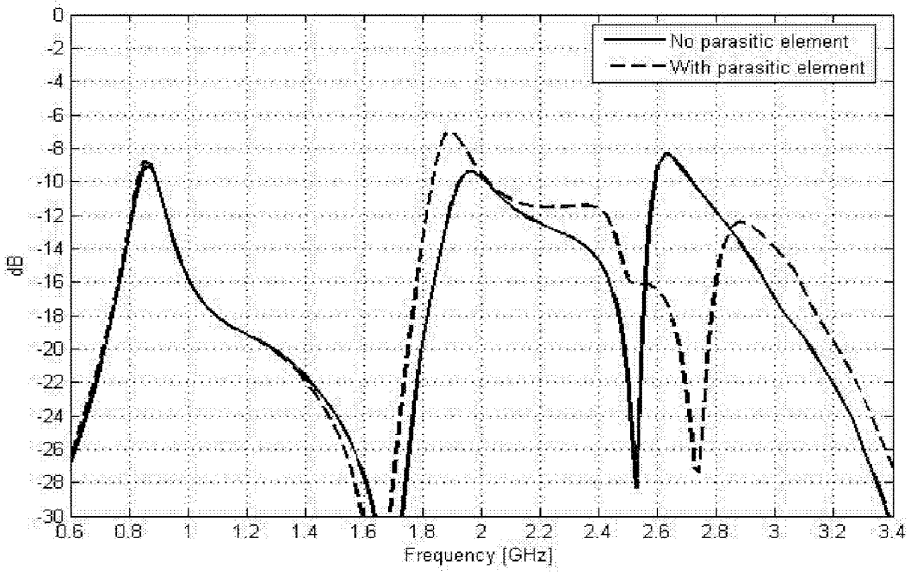

No parasitic element
With parasitic element
dB
Frequency [GHz]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4

Fig. 16

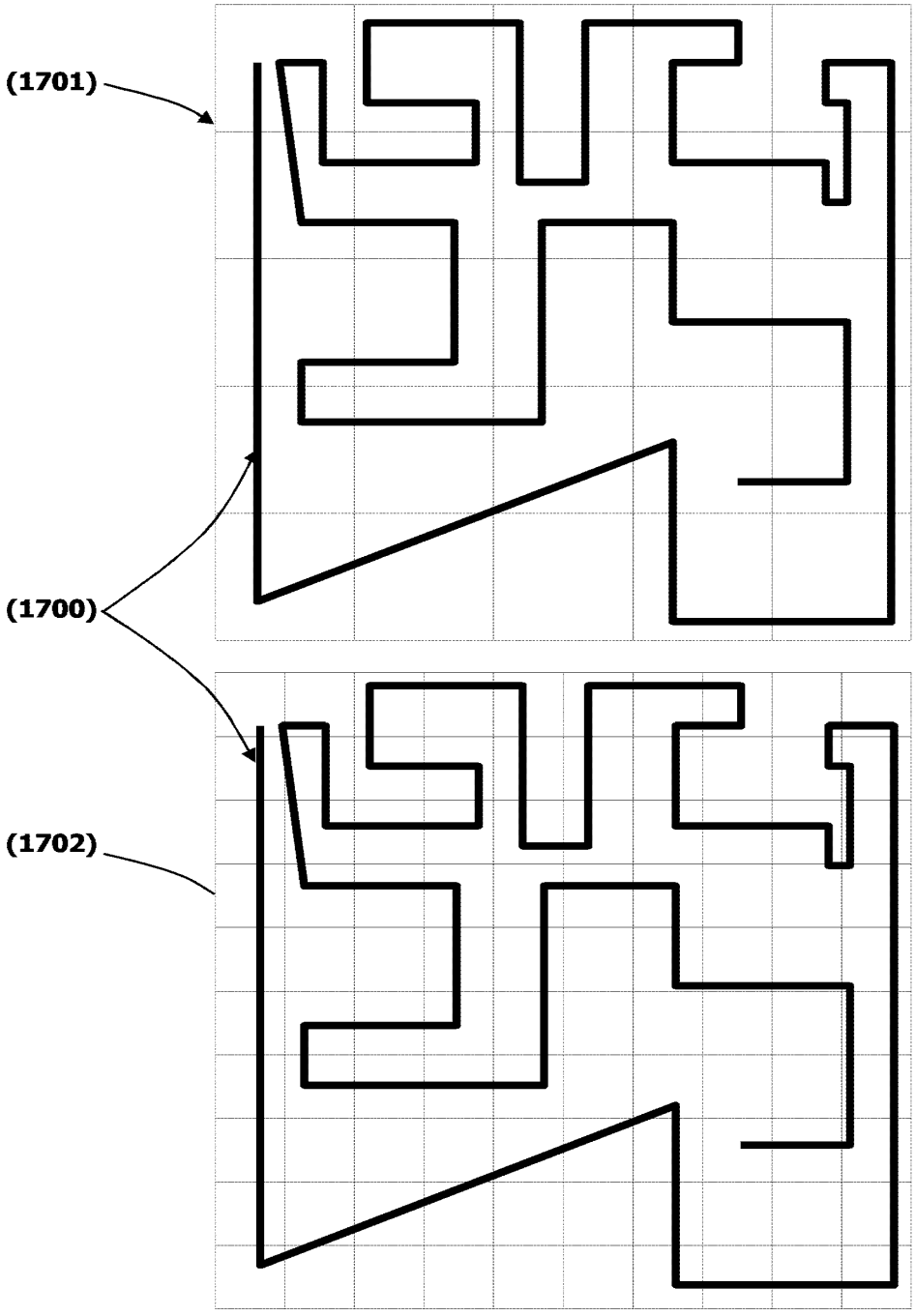


Fig. 17

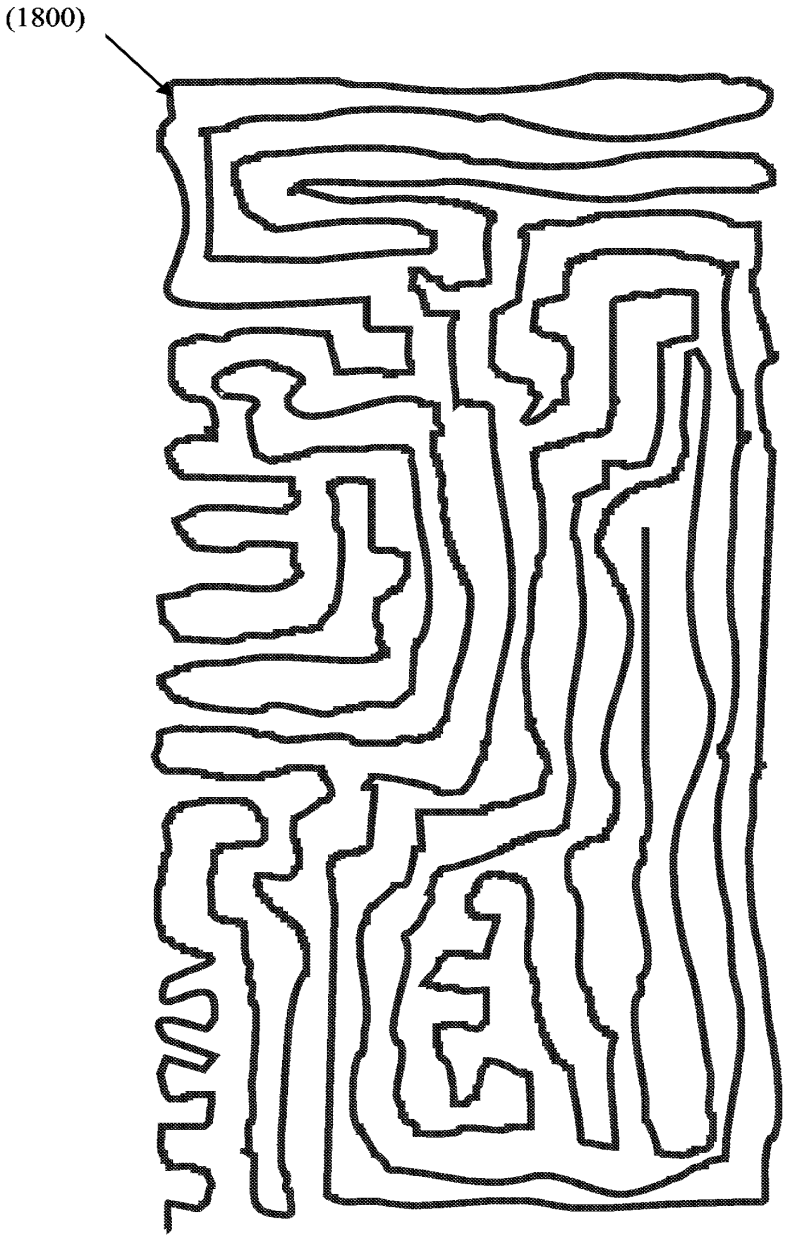


Fig. 18

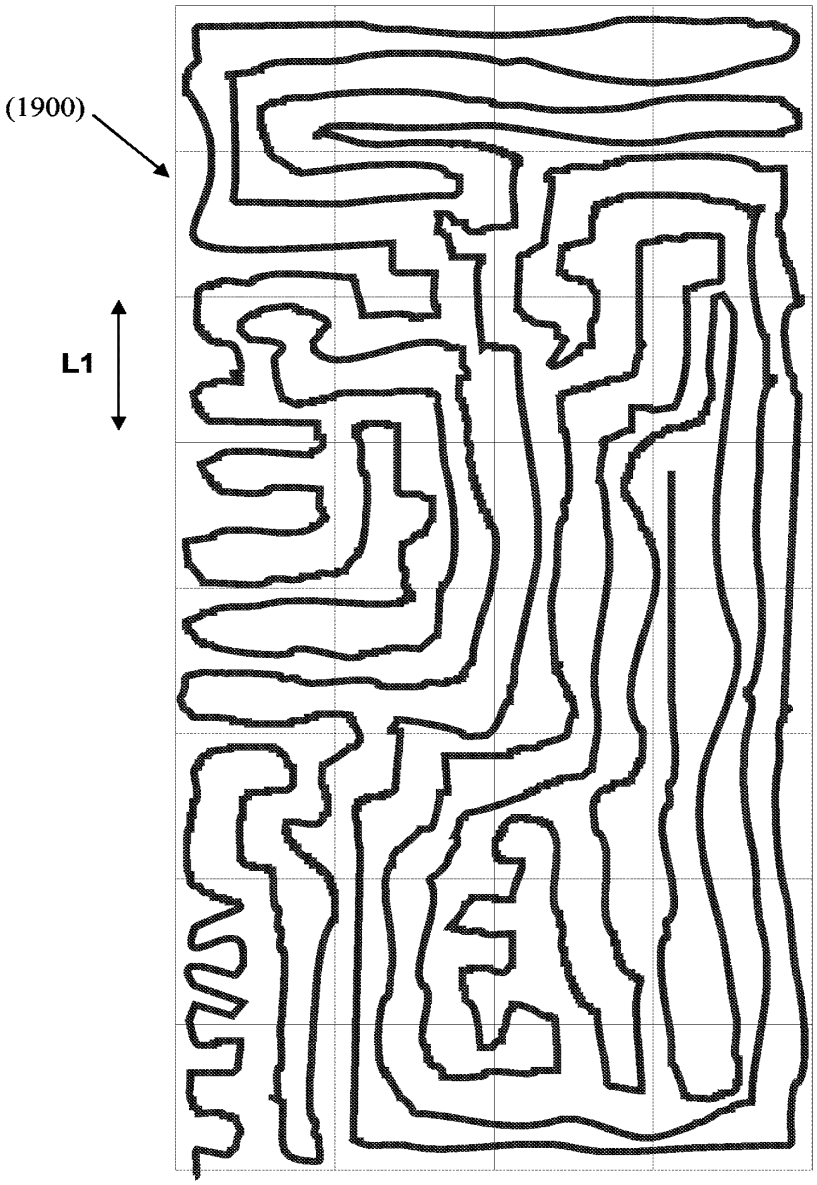


Fig. 19

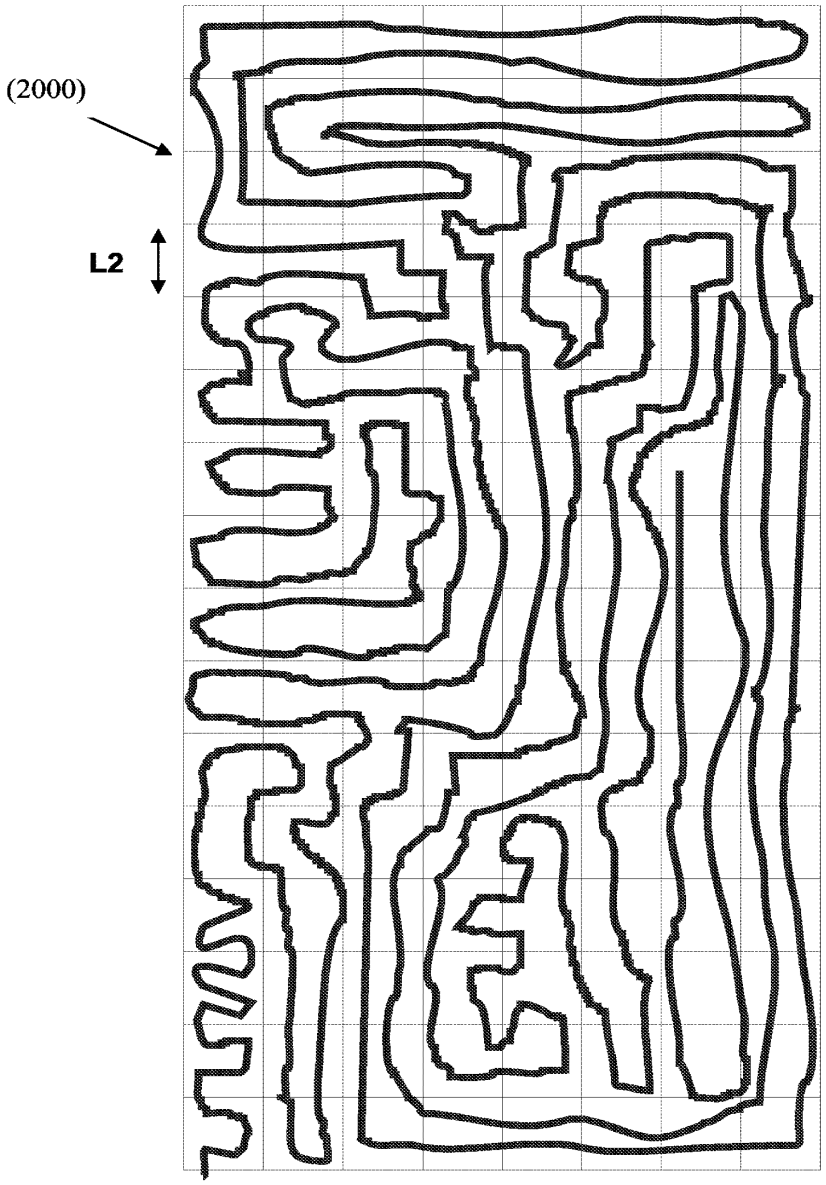


Fig. 20

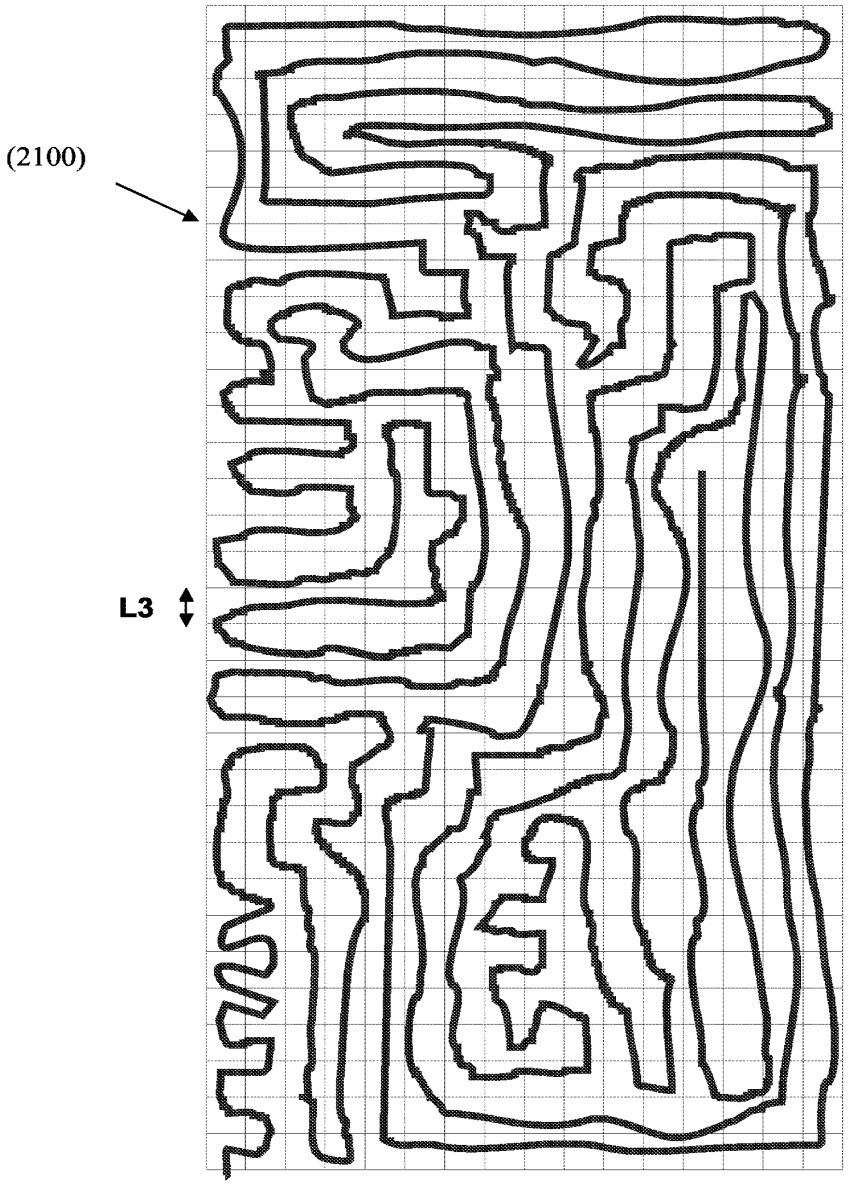


Fig. 21

Corrected Application Data Sheet

Inventor Information

Inventor Number::	1
Given Name::	Josep
Family Name::	Mumbru
City of Residence::	Barcelona
Country of Residence::	Spain
Street of mailing address::	Consell de Cent, 322
City of mailing address::	Barcelona
Country of mailing address::	Spain
Postal or Zip Code of mailing address::	08007

Inventor Number::	2
Given Name::	Jaume
Family Name::	Anguera
City of Residence::	Castellon
Country of Residence::	Spain
Street of mailing address::	Paseo Blasco Ibañez
	15-2, Vinaros
City of mailing address::	Castellon
Country of mailing address::	Spain

Postal or Zip Code of mailing address::	E-12500
Inventor Number::	3
Given Name::	Jordi
Family Name::	Soler
City of Residence::	~~Mataro~~ Sant Cugat del Valles
Country of Residence::	Spain
Street of mailing address::	~~Fray Luis de Leon, 19-21 Atico~~ Alcalde Barnils, 64-68, Modul C, 3a planta
City of mailing address::	~~Mataro~~ Sant Cugat del Valles
Country of mailing address::	Spain
Postal or Zip Code of mailing address::	~~E-08302~~ 08174
Inventor Number::	4
Given Name::	Carles
Family Name::	Puente
City of Residence::	Sant Cugat del Valles
Country of Residence::	Spain
Street of mailing address::	~~Verdi, 45~~ Alcalde Barnils, 64-68, Modul C, 3a planta
City of mailing address::	Sant Cugat del Valles
Country of mailing address::	Spain

Postal or Zip Code of mailing address::	~~08172~~ 08174

Correspondence Information

Correspondence Customer Number::	61060

Application Information

Application Number::	13/718,348
Application Type::	Regular
Subject Matter::	Utility
CD-ROM or CD-R?::	None
Sequence submission?::	None
Computer Readable Form (CRF)?::	No
Title::	HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS
Attorney Docket Number::	47005-P040WUSC2
Request for Early Publication?::	No
Request for Non-Publication?::	No
Small Entity?::	No
Petition included?::	No
Secrecy Order in Parent Appl.?::	No
Authorization to Permit Access::	No

Representative Information

Domestic Priority Information

Application::	Continuity Type::	Parent Application::	Parent Filing Date::
This Application	Continuation of	13/341,051	12/30/11
13/341,051	Continuation of	11/988888	09/30/08
11/988888	National Stage of	PCT/EP2006/007050	07/18/06
PCT/EP2006/007050	Provisional Priority under 35 U.S.C. 119(e)	60/702,205	07/25/05

Foreign Priority Information

Country::	Application number::	Filing Date::	Priority Claimed::
European Patent Office	05106694.2	07/21/05	Yes

Applicant Information

Applicant Number::	1
Applicant Type::	Assignee
Organization Name::	Fractus, S.A.
Street of mailing address::	Alcalde Barnils, 64-68
	Modul C, 3rd Floor
City of mailing address::	Sant Cugat del Valles
Country of mailing address::	Spain

Postal or Zip Code of mailing address:: 08174

Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.			
Signature	/Shoaib A. Mithani/	Date	June 19, 2013
Name (Print/Type)	Shoaib A. Mithani	Registration No. (Attorney/Agent)	61,654

Corrected 13718348 12/18/2012 06/19/2013

Electronic Acknowledgement Receipt

EFS ID:	16082085
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	19-JUN-2013
Filing Date:	18-DEC-2012
Time Stamp:	13:05:39
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	Application Data Sheet	47005CorrectedADS.pdf	20790 546bb7666f934993a2ded0692ba3f8afd6bdc416	no	6

Warnings:	
Information:	

This is not an USPTO supplied ADS fillable form	
Total Files Size (in bytes):	20790

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 37 CFR § 1.6(a)(4).

Dated: June 19, 2013
Electronic Signature for Brenda I. Brown: /Brenda I. Brown/

Docket No.: 47005-P040WUSC2
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Joseph Mumbru et al.

Application No.: 13/718,348 | Confirmation No.: 8109

Filed: December 18, 2012 | Art Unit: 2821

For: HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS | Examiner: Not Yet Assigned

REQUEST FOR CORRECTED FILING RECEIPT

Office of Initial Patent Examination's Filing Receipt Corrections
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Madam:

Applicant hereby requests that a corrected Filing Receipt be issued in the above-identified patent application. The official Filing Receipt received by Applicant, a copy of which is attached hereto, has an error in

Error to be Corrected: (1) Inventor Jordi Soler's residence city is incorrect as Mataro as opposed to Sant Cugat del Valles.

Requested Correction: (1) Please change residence city from Mataro to Sant Cugat del Valles.

Applicant additionally requests that all pertinent U.S. Patent and Trademark Office records relating to the subject application be changed to reflect this correction.

Dated: June 19, 2013

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

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	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/718,348	12/18/2012	2821	1390	47005-P040WUSC2	20	3

RECEIVED ON

CONFIRMATION NO. 8109

UPDATED FILING RECEIPT

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

BY WINSTEAD

OC000000061582875

Date Mailed: 05/30/2013

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Josep Mumbru, Barcelona, SPAIN;
Jaume Anguera, Castellon, SPAIN;
Jordi Soler, Mataro, SPAIN; Sant Cugat del Valles
Carles Puente, Sant Cugat del Valles, SPAIN;

Applicant(s)

Fractus, S.A., Sant Cugat del Valles, SPAIN

Assignment For Published Patent Application

Fractus, S.A., Sant Cugat del Valles, SPAIN

DOCKETED ON

JUN 05 2013

By:

Power of Attorney: The patent practitioners associated with Customer Number 61060

Domestic Priority data as claimed by applicant

This application is a CON of 13/341,051 12/30/2011 PAT 8362960
which is a CON of 11/988,888 09/30/2008 PAT 8115686
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

Request to Retrieve - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to**

Electronic Acknowledgement Receipt

EFS ID:	16085723
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	19-JUN-2013
Filing Date:	18-DEC-2012
Time Stamp:	15:47:19
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	Miscellaneous Incoming Letter	Request_For_Corrected_Filing_Receipt_1.PDF	51805 0ae6a5456e76c9a306cd4ca5c0d887c5fbd32001	no	3

Warnings:	
Information:	

Total Files Size (in bytes):	51805

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.

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.
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2	8109

61060 7590 07/11/2013

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

EXAMINER	
NGUYEN, HOANG V	
ART UNIT	PAPER NUMBER
2821	

MAIL DATE	DELIVERY MODE
07/11/2013	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. 13/718,348	Applicant(s) MUMBRU ET AL.	
	Examiner HOANG V. NGUYEN	Art Unit 2821	AIA (First Inventor to File) Status No

-- 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 *18 December 2012*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

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) _____ is/are allowed.

7)☒ Claim(s) *21-40* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ 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).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

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)).

* 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) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date *12/28/12*.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

Double Patenting

1. 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 Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Ockert*, 245 F.2d 467, 114 USPQ 330 (CCPA 1957).

A statutory type (35 U.S.C. 101) double patenting rejection can be overcome by canceling or amending the claims that are directed to the same invention 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.

2. Claims 21-40 are rejected under 35 U.S.C. 101 as claiming the same invention as that of claims 1-20 of prior U.S. Patent No. 8,362,960 B2. This is a statutory double patenting rejection.

Examiner determines that the phrase "**capable of** transmitting and receiving electromagnetic wave signals" in line 3 of claim 21 of the instant invention to be the same as the phrase "**configured to** transmit and receive electromagnetic wave signals" in line 3 of claim 1 of U.S. Patent No. 8,362,960 since the terms "capable of" and "configured to" technically derived to the same end result and thus result in the same invention.

Claims 29 and 33 are rejected for the same reason.

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

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

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	13718348
Filing Date	2012-12-18
First Named Inventor	Josep Mumbru
Art Unit	NA
Examiner Name	~~NA~~ Hoang V Nguyen
Attorney Docket Number	47005-P040WUSC2

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	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.N./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

	9	6624789		2003-09-23	Kangasvieri et al	
	10	6985108		2006-01-10	Mikkola et al	
	11	7170450		2007-01-30	Chang	
	12	7193571		2007-03-20	Inatsugu	

If you wish to add additional U.S. Patent citation information please click the Add button.

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	

If you wish to add additional U.S. Published Application citation information please click the Add button.

FOREIGN PATENT DOCUMENTS

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.N./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

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]
	1	1401050	EP		2004-03-24	Filtronic LK Oy		☐
	2	1445821	EP		2004-08-11	Wistron NeWeb Corp		☐
	3	2005341313	JP		2005-12-08	Matsushita Electric Industrial		☐
	4	01/54225	WO		2001-07-26	Fractus		☐
	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		☐

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	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

	11	2006/120250	WO		2006-11-16	Fractus SA		☐

If you wish to add additional Foreign Patent Document citation information please click the Add button

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	Jaggard , D. L. Rebuttal expert report of Dr. Dwight L. Jaggard (redacted version). Fractus. February 16, 2011	☐
	2	Long , S. Rebuttal expert report of Dr. Stuart A. Long (redacted version). Fractus. February 16, 2011	☐
	3	Jaggard , D. L. Expert report of Dwight L. Jaggard (redacted) - expert witness retained by Fractus. Fractus. February 23, 2011	☐
	4	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	☐
	5	Antenna designs for MIMO systems. Antenova. January 1, 2004	☐
	6	Karaboikis , M. et al Compact dual-printed inverted-F antenna diversity systems for portable wireless devices. Antennas and Wireless Propagation Letters, IEEE. January 1, 2004	☐
	7	Latif, S. I. et al. Bandwidth enhancement and size reduction of microstrip slot antennas. Antennas and Propagation, IEEE Transactions on. March 1, 2005	☐
	8	Mavridis , G. A. A planar two-branch diversity antenna for wireless applications. Antennas and Propagation Society International Symposium 2006, IEEE. July 9, 2006	☐

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.N./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

	9	Lindberg , P. et al. Internal active antenna for FM radio reception in mobile handsets. EuCAP. November 8, 2007	☐
	10	PCT/EP2006/007050 - International search report and the written opinion of the International Searching Authority. EPO. December 13, 2006	☐
	11	PCT/EP2006/007050 - Written opinion of the International Searching Authority. EPO. December 13, 2006	☐
	12	US11/988888 - Office action dated on November 24, 2010. USPTO. November 24, 2010	☐
	13	US11/988888 - Amendment and response to restriction requirement. Winstead. December 17, 2010	☐
	14	US11/988888 - Office action dated on October 1, 2011. USPTO. January 10, 2011	☐
	15	US11/988888 - Amendment in response to non-final office action dated on January 10, 2011. Winstead. May 31, 2011	☐
	16	US11/988888 - Notice of allowance dated on July 12, 2011. USPTO. July 12, 2011	☐
	17	US11/988888 - Notice of allowance dated on October 14, 2011. USPTO. October 14, 2011	☐
	18	** US13/341051 - Office action summary dated on February 22, 2012. USPTO. February 22, 2012	☐
	19	** US13/341051 - Response to the office action dated on February 22, 2012. Winstead PC. May 14, 2012	☐

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	13718348
	Filing Date	2012-12-18
	First Named Inventor	Josep Mumbru
	Art Unit	NA
	Examiner Name	NA
	Attorney Docket Number	47005-P040WUSC2

	20	** US13/341051 - Office action summary dated on June 21, 2012. USPTO. June 21, 2012	☐
	21	** US13/341051 - Amendment and Response to the final office action dated on June 21, 2012. Winstead. September 14, 2012	☐
	22	** US13/341051 - Notice of allowance dated on September 24, 2012. USPTO. September 24, 2012	☐

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	07/08/2013

*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.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.N./

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	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	07/08/2013								
	21	✓								
	22	✓								
	23	✓								
	24	✓								
	25	✓								
	26	✓								
	27	✓								
	28	✓								
	29	✓								
	30	✓								
	31	✓								
	32	✓								
	33	✓								
	34	✓								
	35	✓								
	36	✓								
	37	✓								
	38	✓								
	39	✓								
	40	✓								

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	941	antenna with ((transmit$4 with receiv$3) or operat$3) with (three near3 (frequenc$3 or band))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/07/08 16:49
L2	2444760	ground$3	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/07/08 16:49
L3	636	1 and 2	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/07/08 16:49
L4	7043	343/702.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/07/08 16:49
L5	166	3 and 4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/07/08 16:50
L6	3179	antenna with (three near3 (frequenc$3 or band))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/07/08 16:50
L7	118088	(two or second or dual) near3 antenna	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/07/08 16:50
L8	166	2 and 4 and 5 and 6	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/07/08 16:51
L9	1305	(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	2013/07/08 16:52
L10	168	4 and 9	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/07/08 16:52
L11	19	mumbru near3 josep.inv.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/07/08 16:53

7/8/2013 4:53:40 PM

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	MUMBRU ET AL.
	Examiner	Art Unit
	HOANG V NGUYEN	2821

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
343	702, 700MS, 846, 767	7/8/13	HN

SEARCH NOTES		
Search Notes	Date	Examiner
EAST	7/8/13	HN
Inventor name search	7/8/13	HN

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

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
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2

CONFIRMATION NO. 8109

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

PUBLICATION NOTICE

OC000000063595380

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

Publication No.US-2013-0229317-A1
Publication Date:09/05/2013

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: October 3, 2013
Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

Docket No. 47005-P040WUSC2
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Josep Mumbru et al.

Application No. 13/718,348 | Confirmation No. 8109

Filed: December 18, 2012 | 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 or Madam:

INTRODUCTORY COMMENTS

In response to the Office Action dated July 11, 2013, 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 6 of this paper.

AMENDMENTS TO THE CLAIMS

1-40. (Canceled)

41. (New) A wireless handheld or portable device comprising:

a ground plane;

the ground plane is inscribed in a rectangular area comprising a first side and a second side, a length of the second side being greater than a length of the first side;

a first antenna configured to transmit and receive electromagnetic waves corresponding to at least three frequency bands;

the at least three frequency bands being used for mobile communication services;

a second antenna configured to receive electromagnetic waves corresponding to at least one frequency band;

the at least one frequency band being used for wireless connectivity services;

the first antenna extends in a direction substantially parallel to the first side;

the second antenna extends in a direction substantially parallel to the second side;

the first antenna is arranged substantially close to the first side; and

the first antenna and the second antenna are located internally within the wireless handheld or portable device.

42. (New) The wireless handheld or portable device according to claim 41, wherein the second antenna is arranged substantially close to the second side.

43. (New) The wireless handheld or portable device according to claim 42, wherein the second antenna is arranged substantially close to a corner of the rectangular area.

44. (New) The wireless handheld or portable device according to claim 41, wherein the first antenna is arranged substantially close to a corner of the rectangular area.

45. (New) The wireless handheld or portable device according to claim 41, wherein the first antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

46. (New) The wireless handheld or portable device according to claim 45, wherein the second antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

47. (New) The wireless handheld or portable device according to claim 41, wherein the at least one frequency band used for wireless connectivity services corresponds to at least one wireless connectivity service selected from the group comprising: Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, and DMB.

48. (New) A portable device comprising:

a ground plane;

a first antenna configured to transmit and receive electromagnetic waves corresponding to at least three frequency bands;

the at least three frequency bands being used for mobile communication services;

a second antenna configured to operate in at least one frequency band;

the first antenna extends in a direction substantially parallel to a first side of the portable device;

a length of a second side of the portable device is greater than a length of the first side of the portable device;

the first antenna is arranged substantially close to the first side of the portable device;

the second antenna is arranged substantially close to a first corner of the portable device;

the first corner of the portable device corresponding to a first end of the first side with an end of the second side of the portable device; and

the first antenna and the second antenna are located internally within the portable device.

49. (New) The portable device according to claim 48, wherein a portion of an orthogonal projection of the first antenna on a plane containing the ground plane does not overlap with the ground plane.

50. (New) The portable device according to claim 48, wherein the second antenna extends in a direction substantially parallel to the first side.

51. (New) The portable device according to claim 50, wherein the first antenna is arranged substantially close to a second corner of the portable device, and said second corner corresponding to a second end of the first side with an end of a third side of the portable device.

52. (New) The portable device according to claim 48, wherein the at least one frequency band is used for a mobile communication service, and said at least one frequency band being different from the at least three frequency bands.

53. (New) The portable device according to claim 48, wherein the first antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

54. (New) The portable device according to claim 53, wherein the second antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

55. (New) A wireless handheld or portable device comprising:

a ground plane;

the ground plane is inscribed in a rectangular area comprising a first side, a second side and a third side, a length of the second side being greater than a length of the first side and a length of the third side;

a first antenna configured to transmit and receive electromagnetic waves corresponding to at least two frequency bands;

the at least two frequency bands being used for mobile communication services;

a second antenna configured to operate in at least one frequency band;

the at least one frequency band being different from the at least two frequency bands;

the first antenna extends in a direction substantially parallel to the first side;

the first antenna is arranged substantially close to the first side;

the second antenna extends in a direction substantially parallel to the third side;

the second antenna is arranged substantially close to the third side;

a geometry of the first antenna being different than a geometry of the second antenna;

at least one of the first antenna and the second antenna is arranged substantially close to a corner of the rectangular area; and

the first antenna and the second antenna are located internally within the wireless handheld or portable device.

56. (New) The wireless handheld or portable device according to claim 55, wherein the first antenna is substantially close to a first corner of the rectangular area and the second antenna is substantially close to a second corner of the rectangular area.

57. (New) The wireless handheld or portable device according to claim 55, wherein the first antenna is configured to transmit and receive electromagnetic waves corresponding to at least three frequency bands, and the at least three frequency bands being used for mobile communication services.

58. (New) The wireless handheld or portable device according to claim 55, wherein the at least one frequency band is used for a wireless connectivity service selected from the group comprising: Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, and DMB.

59. (New) The wireless handheld or portable device according to claim 55, wherein the first antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

60. (New) The wireless handheld or portable device according to claim 59, wherein the second antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

REMARKS

Claims 41-60 are currently pending in the application. New claims 41-60 have been added. Claims 21-40 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 21-40 stand rejected on the grounds of 35 U.S.C. 101 double patenting as claiming the same invention as that of claims 1-20 of U.S. Patent No. 8,362,960. Claims 21-40 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: October 3, 2013

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:	17033386
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	03-OCT-2013
Filing Date:	18-DEC-2012
Time Stamp:	15:49:29
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	31837 85459abacd8c542ada0c9aceeea9069dcb99b0ec	no	6

Warnings:	
Information:	

Total Files Size (in bytes):	31837

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 (09-11)
Approved for use through 1/31/2014. 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 13/718,348	Filing Date 12/18/2012	☐ To be Mailed

ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)		
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	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 $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).			
☐ 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	

APPLICATION AS AMENDED – PART II

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

		(Column 1)		(Column 2)	(Column 3)		
	10/03/2013	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X $80 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	*** 3	= 0	X $420 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	**0**

* 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.

LIE
/C. Dessau/

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
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.
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2	8109

61060 7590 10/23/2013

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

EXAMINER	
NGUYEN, HOANG V	
ART UNIT	PAPER NUMBER
2845	
MAIL DATE	DELIVERY MODE
10/23/2013	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. 13/718,348	Applicant(s) MUMBRU ET AL.	
	Examiner HOANG V. NGUYEN	Art Unit 2845	AIA (First Inventor to File) Status No

-- 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 *10/3/2013*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

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) *41-60* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☒ Claim(s) *41-54* is/are allowed.

7)☒ Claim(s) *55-60* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ 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).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

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)).

* 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) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

The present application is being examined under the pre-AIA first to invent provisions.

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of pre-AIA 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 55-60 are rejected under pre-AIA 35 U.S.C. 102(b) as being anticipated by Honda et al (US 6,992,627 B1).

Regarding claim 55, Honda (Figure 4) discloses a wireless handheld or portable device comprising a ground plane 20; the ground plane is inscribed in a rectangular area comprising a first side (right short side), a second side (long side) and a third side (left short side), a length of the second side being greater than a length of the first side and a length of the third side; a first antenna 54 configured to transmit and receive electromagnetic waves corresponding to at least two frequency bands (col 5, lines 30-36); the at least two frequency bands being used for mobile communication services; a second antenna 14 configured to operate in at least one frequency band; the at least one frequency band being different from the at least two frequency bands (col 4, lines 51-52); the first antenna extends in a direction substantially parallel to the first side; the first antenna is arranged substantially close to the first side; the second antenna extends in a direction substantially parallel to the third side; the second antenna is arranged substantially close to the third side; a geometry of the first antenna being different than a geometry of the

second antenna; at least one of the first antenna and the second antenna is arranged substantially close to a comer of the rectangular area; and the first antenna and the second antenna are located internally within the wireless handheld or portable device.

Regarding claim 56, as applied to claim 55, Figure 4 of Honda shows that the first antenna 54 is substantially close to a first corner of the rectangular area and the second antenna 14 is substantially close to a second comer of the rectangular area.

Regarding claim 57, as applied to claim 55, Honda (col 5, lines 30-36) teaches that the first antenna 54 is configured to transmit and receive electromagnetic waves corresponding to at least three frequency bands, and the at least three frequency bands being used for mobile communication services.

Regarding claim 58, as applied to claim 55, Honda (col 4, lines 51-52 and col5, lines 30-36) teaches that the at least one frequency band is used for a wireless connectivity service selected from the group comprising: Bluetooth ^{TM,} IEEES02.1 la, IEEES02.1 lb, IEEES02.1 lg, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, and DMB.

Regarding claim 59, as applied to claim 55, Figure 4 of Honda shows that the first antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

Regarding claim 60, as applied to claim 59, Figure 4 of Honda shows that the second antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

Allowable Subject Matter

3. Claims 41-54 are allowed.

4. The following is a statement of reasons for the indication of allowable subject matter:

Regarding claim 41, Honda discloses a wireless handheld or portable device comprising a ground plane; the ground plane is inscribed in a rectangular area comprising a first side and a second side, a length of the second side being greater than a length of the first side; a first antenna configured to transmit and receive electromagnetic waves corresponding to at least three frequency bands; the at least three frequency bands being used for mobile communication services; a second antenna configured to receive electromagnetic waves corresponding to at least one frequency band; the at least one frequency band being used for wireless connectivity services; the first antenna extends in a direction substantially parallel to the first side; the first antenna is arranged substantially close to the first side; and the first antenna and the second antenna are located internally within the wireless handheld or portable device. Honda, however, fails to specifically teach that the second antenna extends in a direction substantially parallel to the second side.

Claims 42-47 are allowed for depending on claim 41.

Regarding claim 48, Honda discloses a portable device comprising a ground plane; a first antenna configured to transmit and receive electromagnetic waves corresponding to at least three frequency bands; the at least three frequency bands being used for mobile communication services; a second antenna configured to operate in at least one frequency band; the first antenna extends in a direction substantially parallel to a first side of the portable device; a length of a second side of the portable device is greater than a length of the first side of the

portable device; the first antenna is arranged substantially close to the first side of the portable device; and the first antenna and the second antenna are located internally within the portable device. Honda, however, fails to specifically teach that the second antenna is arranged substantially close to a first corner of the portable device; the first corner of the portable device corresponding to a first end of the first side with an end of the second side of the portable device.

Claims 49-54 are allowed for depending on claim 48.

Conclusion

5. 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.

6. 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 2845

Notice of References Cited	Application/Control No. 13/718,348	Applicant(s)/Patent Under Reexamination MUMBRU ET AL.	
	Examiner HOANG V. NGUYEN	Art Unit 2845	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,992,627	01-2006	Honda et al.	343/700MS
	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.

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	7830	343/702.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 08:47
L2	326939	(two or second or dual or multi$3 or plurality) near3 (antenna or radiat$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 08:48
L3	62412	ground adj plane	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 08:48
L4	893316	pcb or (circuit adj board)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 08:48
L5	9862	2 with (3 or 4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 08:49
L6	1826	1 and 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 08:49
L7	105313	three near4 (frequenc$3 or band or resonance)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 08:54
L8	293	6 and 7	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 08:54
L9	162	(first adj antenna) with ((first or one) near3 end) with ((ground adj plane) or pcb or (circuit adj board))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 09:04
L10	148	(second adj antenna) with ((second or other or another or opposite) near3 end) with ((ground adj plane) or pcb or (circuit adj board))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 09:04

L11	73	9 and 10	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 09:05
L12	2	mumbru near3 joseph.inv.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 09:07
L13	20	mumbru near3 josep.inv.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/10/21 09:07

10/21/2013 9:08:33 AM

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	MUMBRU ET AL.
	Examiner	Art Unit
	HOANG V NGUYEN	2821

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
343	702, 700MS, 846, 767	7/8/13	HN
343	702, 700MS, 846, 767	10/21/13	HN

SEARCH NOTES		
Search Notes	Date	Examiner
EAST	7/8/13	HN
Inventor name search	7/8/13	HN
EAST	10/21/13	HN

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	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	07/08/2013	10/21/2013							
	21	✓	-							
	22	✓	-							
	23	✓	-							
	24	✓	-							
	25	✓	-							
	26	✓	-							
	27	✓	-							
	28	✓	-							
	29	✓	-							
	30	✓	-							
	31	✓	-							
	32	✓	-							
	33	✓	-							
	34	✓	-							
	35	✓	-							
	36	✓	-							
	37	✓	-							
	38	✓	-							
	39	✓	-							
	40	✓	-							
	41		=							
	42		=							
	43		=							
	44		=							
	45		=							
	46		=							
	47		=							
	48		=							
	49		=							
	50		=							
	51		=							
	52		=							
	53		=							
	54		=							
	55		✓							
	56		✓							

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	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	07/08/2013	10/21/2013							
	57		✓							
	58		✓							
	59		✓							
	60		✓							

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	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/718,348	12/18/2012	2845	1390	47005-P040WUSC2	20	3

CONFIRMATION NO. 8109

CORRECTED FILING RECEIPT

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

OC000000065917928

Date Mailed: 01/06/2014

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Josep Mumbru, Barcelona, SPAIN;
Jaume Anguera, Castellon, SPAIN;
Jordi Soler, Sant Cugat del Valles, SPAIN;
Carles Puente, Sant Cugat del Valles, SPAIN;

Applicant(s)

FRACTUS, S.A., Sant Cugat del Valles, SPAIN

Assignment For Published Patent Application

Fractus, S.A., Sant Cugat del Valles, SPAIN

Power of Attorney: The patent practitioners associated with Customer Number 61060

Domestic Priority data as claimed by applicant

This application is a CON of 13/341,051 12/30/2011 PAT 8362960
which is a CON of 11/988,888 09/30/2008 PAT 8115686
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

Request to Retrieve - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to**

Retrieve Electronic Priority Application(s) (PTO/SB/38 or its equivalent). Consequently, the USPTO will attempt to electronically retrieve these priority documents.

If Required, Foreign Filing License Granted: 01/18/2013

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/718,348**

Projected Publication Date: Not Applicable

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

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications:

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific

countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

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 U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop

technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

PTO/SB/30 (07-09)
Approved for use through 07/31/2012. OMB 0651-0031
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.

Request for Continued Examination (RCE) Transmittal

Address to:
Mail Stop RCE
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Application Number	13/718,348-Conf. #8109
Filing Date	December 18, 2012
First Named Inventor	Joseph Mumbru
Art Unit	2845
Examiner Name	H. V. Nguyen
Attorney Docket Number	47005-P040WUSC2

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.

Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. See Instruction Sheet for RCEs (not to be submitted to the USPTO) on page 2.

1. Submission required under 37 CFR 1.114 Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

   a. [ ] Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.

      i. [ ] Consider the arguments in the Appeal Brief or Reply Brief previously filed on _____

      ii. [ ] Other _____

   b. [x] Enclosed

      i. [x] Amendment/Reply

      ii. [ ] Affidavit(s)/Declaration(s)

      iii. [ ] Information Disclosure Statement (IDS)

      iv. [ ] Other _____

2. Miscellaneous

   a. [ ] Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of _____ months. (Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)

   b. [ ] Other _____

3. Fees The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.

   a. [x] The Director is hereby authorized to charge the following fees, any underpayment of fees, or credit any Overpayments, to Deposit Account No. 23-2426 .

      i. [x] RCE fee required under 37 CFR 1.17(e)

      ii. [ ] Extension of time fee (37 CFR 1.136 and 1.17)

      iii. [ ] Other _____

   b. [ ] Check in the amount of $ _____ enclosed

   c. [ ] Payment by credit card (Form PTO-2038 enclosed)

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

Signature	/Shoaib A. Mithani/	Date	January 22, 2014
Name (Print/Type)	Shoaib A. Mithani	Registration No.	61,654

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 22, 2014
Electronic Signature for Kimberly Benline: /Kimberly Benline/

Docket No. 47005-P040WUSC2
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Josep Mumbru et al.

Application No. 13/718,348 | Confirmation No. 8109

Filed: December 18, 2012 | Art Unit: 2845

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 Office Action dated October 23, 2013, 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

1-40. (Canceled)

41. (Previously Presented) A wireless handheld or portable device comprising:

a ground plane;

the ground plane is inscribed in a rectangular area comprising a first side and a second side, a length of the second side being greater than a length of the first side;

a first antenna configured to transmit and receive electromagnetic waves corresponding to at least three frequency bands;

the at least three frequency bands being used for mobile communication services;

a second antenna configured to receive electromagnetic waves corresponding to at least one frequency band;

the at least one frequency band being used for wireless connectivity services;

the first antenna extends in a direction substantially parallel to the first side;

the second antenna extends in a direction substantially parallel to the second side;

the first antenna is arranged substantially close to the first side; and

the first antenna and the second antenna are located internally within the wireless handheld or portable device.

42. (Previously Presented) The wireless handheld or portable device according to claim 41, wherein the second antenna is arranged substantially close to the second side.

43. (Previously Presented) The wireless handheld or portable device according to claim 42, wherein the second antenna is arranged substantially close to a corner of the rectangular area.

44. (Previously Presented) The wireless handheld or portable device according to claim 41, wherein the first antenna is arranged substantially close to a corner of the rectangular area.

45. (Previously Presented) The wireless handheld or portable device according to claim 41, wherein the first antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

46. (Previously Presented) The wireless handheld or portable device according to claim 45, wherein the second antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

47. (Previously Presented) The wireless handheld or portable device according to claim 41, wherein the at least one frequency band used for wireless connectivity services corresponds to at least one wireless connectivity service selected from the group comprising: Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, and DMB.

48. (Previously Presented) A portable device comprising:

a ground plane;

a first antenna configured to transmit and receive electromagnetic waves corresponding to at least three frequency bands;

the at least three frequency bands being used for mobile communication services;

a second antenna configured to operate in at least one frequency band;

the first antenna extends in a direction substantially parallel to a first side of the portable device;

a length of a second side of the portable device is greater than a length of the first side of the portable device;

the first antenna is arranged substantially close to the first side of the portable device;

the second antenna is arranged substantially close to a first corner of the portable device;

the first corner of the portable device corresponding to a first end of the first side with an end of the second side of the portable device; and

the first antenna and the second antenna are located internally within the portable device.

49. (Previously Presented) The portable device according to claim 48, wherein a portion of an orthogonal projection of the first antenna on a plane containing the ground plane does not overlap with the ground plane.

50. (Currently Amended) The portable device according to claim 48, wherein the second antenna is substantially close to the first side of the portable device and extends in a direction substantially parallel to the first side of the portable device.

51. (Canceled)

52. (Previously Presented) The portable device according to claim 48, wherein the at least one frequency band is used for a mobile communication service, and said at least one frequency band being different from the at least three frequency bands.

53. (Previously Presented) The portable device according to claim 48, wherein the first antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

54. (Previously Presented) The portable device according to claim 53, wherein the second antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

55. (Currently Amended) A wireless handheld or portable device comprising:

a ground plane;

the ground plane is inscribed in a first rectangular area comprising a first side, a second side and a third side, a length of the second side being greater than a length of the first side and a length of the third side;

a first antenna configured to transmit and receive electromagnetic waves corresponding to at least two frequency bands;

the at least two frequency bands being used for mobile communication services;

a second antenna configured to operate in at least one frequency band;

the at least one frequency band being different from the at least two frequency bands;

the first antenna extends in a direction substantially parallel to the first side;

the first antenna is proximate ~~arranged substantially close~~ to the first side;

the second antenna extends in a direction substantially parallel to the third side;

the second antenna is proximate ~~arranged substantially close~~ to the third side;

the second antenna is inscribed in a second rectangular area;

a sum of a length and a width of the second rectangular area is smaller than a quarter of an operating wavelength of the second antenna;

a geometry of the first antenna being different than a geometry of the second antenna;

at least one of the first antenna and the second antenna is proximate ~~arranged substantially close~~ to a corner of the first rectangular area; and

the first antenna and the second antenna are located internally within the wireless handheld or portable device.

56. (Currently Amended) The wireless handheld or portable device according to claim 55, wherein the first antenna is proximate ~~substantially close~~ to a first corner of the first rectangular area and the second antenna is proximate ~~substantially close~~ to a second corner of the first rectangular area.

57. (Currently Amended) The wireless handheld or portable device according to claim 55, wherein the second antenna is contained in a plane substantially parallel to a plane containing the ground plane ~~the first antenna is configured to transmit and receive electromagnetic waves corresponding to at least three frequency bands, and the at least three frequency bands being used for mobile communication services~~.

58. (Previously Presented) The wireless handheld or portable device according to claim 55, wherein the at least one frequency band is used for a wireless connectivity service selected from the group comprising: Bluetooth™, IEEE802.11a, IEEE802.11b, IEEE802.11g, WLAN, WiFi, UWB, ZigBee, GPS, Galileo, SDARs, XDARS, WiMAX, DAB, FM, DVB-H, and DMB.

59. (Previously Presented) The wireless handheld or portable device according to claim 55, wherein the first antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

60. (Previously Presented) The wireless handheld or portable device according to claim 59, wherein the second antenna is an antenna selected from the group comprising: a monopole antenna, an inverted-F antenna, a patch antenna, and a planar inverted-F antenna.

61. (New) The wireless handheld or portable device according to claim 55, wherein the second antenna is fitted over a curved surface.

REMARKS

Reconsideration of the application is respectfully requested. Claims 41-50 and 52-61 are currently pending in the application. Claims 50 and 55-57 have been amended. Claim 51 has been canceled. New claim 61 has been added. Applicant respectfully submits that no new matter has been added.

I. Allowed Claims

The Examiner has indicated that claims 41-54 are allowed. Applicant thanks the Examiner for the indication of allowable subject matter.

II. Rejection under 35 USC § 102

Claims 55-60 stand rejected under 35 U.S.C. 102(b) as anticipated by U.S. Patent No. 6,992,627 to Honda et al. ("Honda").

Independent claim 55 relates to a wireless handheld or portable device. Applicant respectfully submits that Honda fails to disclose at least the features of amended independent claim 55 of "the second antenna is inscribed in a second rectangular area . . . a sum of a length and a width of the second rectangular area is smaller than a quarter of an operating wavelength of the second antenna."

Honda teaches a resonator element (14) having a pair of opposed surfaces (16,18), wherein a first conductor trace (26) is disposed upon the surface (16) of the resonator element (14), and the second conductor traces (28) are disposed upon the opposite surface (18) of the resonator element (14).[1] The first conductor trace element (26) is an electrical quarter wave resonator for 1575 MHz and the second conductor trace elements (28) form a feed network.[2] The rectangular area in which the resonator element (14) is inscribed features a length that is greater than a quarter wavelength since the second conductor trace elements (28) are larger than the first conductor trace element (26) and the first conductor trace element corresponds to a quarter wave resonator. Therefore, Honda fails to disclose a second antenna (the resonator element (14) that is inscribed in a second rectangular area, a sum of a length and a width of the

[1] *Honda,* Col. 4, lines 24-36, lines 51-69.
[2] *Honda*, Fig. 2, Col. 5, lines 7-11.

second rectangular area is smaller than a quarter of an operating wavelength of the second antenna as required by amended independent claim 55. For the reason set forth above, Applicant respectfully submits that amended independent claim 55 patentably distinguishes over Honda and is in condition for allowance.

Dependent claims 56-61 depend from and further limit amended independent claim 55 in a patentable sense. These dependent claims are therefore deemed to distinguish over Honda for at least the same reasons as those set forth above relative to the rejection of amended independent claim 55 and are in condition for allowance.

In addition, Applicant respectfully submits that Honda fails to disclose at least the features of dependent claim 57 of "the second antenna is contained in a plane substantially parallel to a plane containing the ground plane." According to Honda, a first resonator element (14) is arranged on a first side of a wireless communications device and a second antenna (54) is disposed at an end opposite to the first resonator element (14).[3] In this arrangement illustrated in Fig.4, the resonator element (14) is disposed in a substantially perpendicular relationship to the ground plane element (20).[4] Thus, Honda fails to disclose that the second antenna (in this case, the first resonator element, 14) is contained in a plane substantially parallel to a plane containing the ground plane as required by dependent claim 57. For at least this additional reason, Applicant respectfully submits that dependent claim 57 patentably distinguishes over Honda and is in condition for allowance.

In another embodiment (*Honda*, Fig.6), Honda discloses a GPS band antenna (14) and a wireless frequency band antenna (54), wherein the GPS band antenna is contained in a plane substantially parallel to a plane containing the ground plane element (20). However, the wireless frequency band antenna (54) is not disposed at an end opposite to the GPS antenna (14) as required by amended independent claim 55. Moreover, Honda is silent regarding arranging the GPS band antenna substantially parallel to the ground plane, when the wireless frequency band antenna (54) is disposed at an end opposite to the GPS band antenna (14). According to the

[3] *Honda,* Col. 5, lines 16-24.
[4] *Honda,* Col. 4, lines 24-26.

disclosure of Honda, the skilled in the art would arrange the GPS antenna as in Fig. 4 or as in Fig. 6 but not as required by dependent claim 57.

Newly added claim 61, which depends from amended independent claim 55, requires that the second antenna is fitted over a curved surface. In contrast, the wireless frequency band antenna (54) taught by Honda is fitted over a planar surface that is the dielectric substrate (56), and the GPS band antenna (14) is also fitted over a planar surface, particularly it is fitted over substrate (40). Thus, Honda fails to disclose the second antenna being fitted over a curved surface as required by new dependent claim 61. For the reason set forth above, Applicant respectfully submits that new dependent claim 61 patentably distinguishes over Honda and is 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: January 22, 2014

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 Patent Application Fee Transmittal	
Application Number:	13718348
Filing Date:	18-Dec-2012
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/Kimberly Benline
Attorney Docket Number:	47005-P040WUSC2
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:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Request for Continued Examination	1801	1	1200	1200
		Total in USD ($)		**1200**

Electronic Acknowledgement Receipt	
EFS ID:	17981076
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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/Kimberly Benline
Filer Authorized By:	Shoaib Amirali Mithani
Attorney Docket Number:	47005-P040WUSC2
Receipt Date:	22-JAN-2014
Filing Date:	18-DEC-2012
Time Stamp:	10:58:09
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$1200
RAM confirmation Number	7475
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 1.16 (National application filing, search, and examination fees) Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)	

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)

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	Request for Continued Examination (RCE)	RCE.PDF	26875 8f08fe54d7e573c005de8183eae005f8fb5bae6c	no	1
Warnings:					
This is not a USPTO supplied RCE SB30 form.					
Information:					
2	Amendment Submitted/Entered with Filing of CPA/RCE	ResponseToFinalOfficeAction.PDF	43690 4a23a9eb6943a8e7ffdc25437603c42f45831b6c	no	9
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30658 61d21ab65694eefbfeb94b5193e9220ae11d9db9	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	101223		

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.

Electronic Acknowledgement Receipt	
EFS ID:	17981076
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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/Kimberly Benline
Filer Authorized By:	Shoaib Amirali Mithani
Attorney Docket Number:	47005-P040WUSC2
Receipt Date:	22-JAN-2014
Filing Date:	18-DEC-2012
Time Stamp:	10:58:09
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$1200
RAM confirmation Number	7475
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 1.16 (National application filing, search, and examination fees) Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)	

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)	
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	Request for Continued Examination (RCE)	RCE.PDF	26875 8f08fe54d7e573c005de8183eae005f8fb5bae6c	no	1
Warnings:					
This is not a USPTO supplied RCE SB30 form.					
Information:					
2	Amendment Submitted/Entered with Filing of CPA/RCE	ResponseToFinalOfficeAction.PDF	43690 4a23a9eb6943a8e7ffdc25437603c42f45831b6c	no	9
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30658 61d21ab65694eefbfeb94b5193e9220ae11d9db9	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	101223		

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 (09-11)
Approved for use through 1/31/2014. 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 13/718,348	Filing Date 12/18/2012	☐ To be Mailed

ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)		
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	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 $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).			
☐ 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	

APPLICATION AS AMENDED – PART II

AMENDMENT	01/22/2014	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X $80 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X $420 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	**0**

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

LIE
/TINA M. BELL/

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
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

61060 7590 02/04/2014

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

EXAMINER	
NGUYEN, HOANG V	
ART UNIT	PAPER NUMBER
2845	

DATE MAILED: 02/04/2014

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2	8109

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

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$960	$0	$0	$960	05/05/2014

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 ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

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.

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 02/04/2014
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.
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2	8109

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

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$960	$0	$0	$960	05/05/2014

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, HOANG V	2845	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 credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ❑ Applicant certifying micro entity status. See 37 CFR 1.29 — NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
- ❑ Applicant asserting small entity status. See 37 CFR 1.27 — NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
- ❑ Applicant changing to regular undiscounted fee status. — NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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.
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2	8109

61060 7590 02/04/2014

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

EXAMINER	
NGUYEN, HOANG V	
ART UNIT	PAPER NUMBER
2845	

DATE MAILED: 02/04/2014

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.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B 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.

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. 13/718,348	Applicant(s) MUMBRU ET AL.	
	Examiner HOANG V. NGUYEN	Art Unit 2845	AIA (First Inventor to File) Status No

-- 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 *RCE filed on 1/22/2014*.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on_____.
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 *41-50 and 52-61*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov .
4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   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. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ 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).
6. ☐ 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. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
5. ☐ Examiner's Amendment/Comment
6. ☒ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/HOANG V NGUYEN/
Primary Examiner, Art Unit 2845

The present application is being examined under the pre-AIA first to invent provisions.

Allowable Subject Matter

1. Claims 41-50 and 52-61 are allowed.

2. The following is an examiner's statement of reasons for allowance:

Regarding claim 55, Honda et al (US 6,992,627 B1) discloses a wireless handheld or portable device comprising a ground plane; the ground plane is inscribed in a first rectangular area comprising a first side, a second side and a third side, a length of the second side being greater than a length of the first side and a length of the third side; a first antenna configured to transmit and receive electromagnetic waves corresponding to at least two frequency bands; the at least two frequency bands being used for mobile communication services; a second antenna configured to operate in at least one frequency band; the at least one frequency band being different from the at least two frequency bands; the first antenna extends in a direction substantially parallel to the first side; the first antenna is proximate to the first side; the second antenna extends in a direction substantially parallel to the third side; the second antenna is proximate to the third side; a geometry of the first antenna being different than a geometry of the second antenna; at least one of the first antenna and the second antenna is proximate to a corner of the first rectangular area; and the first antenna and the second antenna are located internally within the wireless handheld or portable device. Honda, however, fails to further teach that the second antenna is inscribed in a second rectangular area; a sum of a length and a width of the

second rectangular area is smaller than a quarter of an operating wavelength of the second antenna.

Claims 56-61 are allowed for depending on claim 55.

Reasons for indicating allowable subject matter for claims 41-50 and 52-54 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 2845

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. 8109

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
13/718,348	12/18/2012 RULE	343	2845	47005-P040WUSC2

APPLICANTS

FRACTUS, S.A., Sant Cugat del Valles, SPAIN

INVENTORS

Josep Mumbru, Barcelona, SPAIN;
Jaume Anguera, Castellon, SPAIN;
Jordi Soler, Sant Cugat del Valles, SPAIN;
Carles Puente, Sant Cugat del Valles, SPAIN;

**** CONTINUING DATA ***************************

This application is a CON of 13/341,051 12/30/2011 PAT 8362960
which is a CON of 11/988,888 09/30/2008 PAT 8115686 /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 ****

01/18/2013

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		
1390	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

BIB (Rev. 05/07).

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	MUMBRU ET AL.
	Examiner	Art Unit
	HOANG V NGUYEN	2821

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
343	702, 700MS, 846, 767	7/8/13	HN
343	702, 700MS, 846, 767	10/21/13	HN
343	702, 700MS, 846, 767, 725	1/28/14	HN

SEARCH NOTES		
Search Notes	Date	Examiner
EAST	7/8/13	HN
Inventor name search	7/8/13	HN
EAST	10/21/13	HN
EAST	1/28/14	HN

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
343	702, 725	1/28/14	HN

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	2	("6992627").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/01/28 08:32
L2	413881	(two or second or dual or multi$3 or plurality) near3 (antenna or radiat$3)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 08:58
L3	71955	ground$3 adj plane	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 08:58
L4	1270451	(circuit adj board) or pcb or pwb or (wiring adj board)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 08:59
L5	13248	2 with (3 or 4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 08:59
L6	1	1 and 5	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 08:59
L7	115831	three near4 (frequenc$3 or band or resonance)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 09:00
L8	938	5 and 7	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 09:00
L9	195	(first adj antenna) with ((first or one) near3 end) with ((ground$3 adj plane) or pcb or (circuit adj board))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 09:01
L10	169	(second adj antenna) with ((second or other or another or opposite) near3 end) with ((ground$3 adj plane) or pcb or (circuit adj board))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 09:02

L11	90	9 and 10	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 09:02
L12	93808	quarter near4 ($4length or wave)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 09:03
L13	1058241	antenna	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 09:03
L14	1156	12 with 13 with (less or smaller)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 09:04
L15	4	11 and 14	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/01/28 09:04

1/28/2014 9:04:51 AM

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	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	07/08/2013	10/21/2013	01/28/2014						
	21	✓	-	-						
	22	✓	-	-						
	23	✓	-	-						
	24	✓	-	-						
	25	✓	-	-						
	26	✓	-	-						
	27	✓	-	-						
	28	✓	-	-						
	29	✓	-	-						
	30	✓	-	-						
	31	✓	-	-						
	32	✓	-	-						
	33	✓	-	-						
	34	✓	-	-						
	35	✓	-	-						
	36	✓	-	-						
	37	✓	-	-						
	38	✓	-	-						
	39	✓	-	-						
	40	✓	-	-						
1	41		=	=						
2	42		=	=						
3	43		=	=						
4	44		=	=						
5	45		=	=						
6	46		=	=						
7	47		=	=						
8	48		=	=						
9	49		=	=						
10	50		=	=						
	51		=	-						
11	52		=	=						
12	53		=	=						
13	54		=	=						
14	55		✓	=						
15	56		✓	=						

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	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	07/08/2013	10/21/2013	01/28/2014						
16	57		✓	=						
17	58		✓	=						
18	59		✓	=						
19	60		✓	=						
20	61			=						

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	MUMBRU ET AL.
	Examiner	**Art Unit**
	HOANG V NGUYEN	2845

CPC		
Symbol	**Type**	**Version**

CPC Combination Sets				
Symbol	**Type**	**Set**	**Ranking**	**Version**

NONE (Assistant Examiner) (Date)		**Total Claims Allowed:** 20	
/HOANG V NGUYEN/ Primary Examiner.Art Unit 2845 (Primary Examiner)	01/28/2014 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 4A & 4B

U.S. Patent and Trademark Office Part of Paper No. 012814

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	MUMBRU ET AL.
	Examiner	**Art Unit**
	HOANG V NGUYEN	2845

US ORIGINAL CLASSIFICATION		INTERNATIONAL CLASSIFICATION										
CLASS	SUBCLASS	CLAIMED					NON-CLAIMED					
343	702	H	0	1	Q	1 / 24 (2006.01.01)						
CROSS REFERENCE(S)												
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)											
343	725											

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	20	
/HOANG V NGUYEN/ Primary Examiner.Art Unit 2845	01/28/2014	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	4A & 4B

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13718348	MUMBRU ET AL.
	Examiner	**Art Unit**
	HOANG V NGUYEN	2845

☐ 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		33	9	49								
	2		18		34	10	50								
	3		19		35		51								
	4		20		36	11	52								
	5		21		37	12	53								
	6		22		38	13	54								
	7		23		39	14	55								
	8		24		40	15	56								
	9		25	1	41	16	57								
	10		26	2	42	17	58								
	11		27	3	43	18	59								
	12		28	4	44	19	60								
	13		29	5	45	20	61								
	14		30	6	46										
	15		31	7	47										
	16		32	8	48										

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 20	
/HOANG V NGUYEN/ Primary Examiner.Art Unit 2845 (Primary Examiner)	01/28/2014 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 4A & 4B

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 02/04/2014
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.
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2	8109

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

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$960	$0	$0	$960	05/05/2014

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, HOANG V	2845	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): Sant Cugat del Valles, 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 credits any overpayment, to Deposit Account Number 232426 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
☐ Applicant certifying micro entity status. See 37 CFR 1.29
NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
☐ Applicant asserting small entity status. See 37 CFR 1.27
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
☐ Applicant changing to regular undiscounted fee status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Shoaib A. Mithani/ Date April 23, 2014
Typed or printed name Shoaib A. Mithani Registration No. 61,654

PTOL-85 Part B (10-13) Approved for use through 10/31/2013 OMB 0651-0033 U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Electronic Patent Application Fee Transmittal

Application Number:	13718348
Filing Date:	18-Dec-2012
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/John Sheridan
Attorney Docket Number:	47005-P040WUSC2

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:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl Issue Fee	1501	1	960	960
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
			Total in USD ($)	**960**

Electronic Acknowledgement Receipt	
EFS ID:	18835382
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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/John Sheridan
Filer Authorized By:	Ross Robinson
Attorney Docket Number:	47005-P040WUSC2
Receipt Date:	23-APR-2014
Filing Date:	18-DEC-2012
Time Stamp:	11:58:27
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$960
RAM confirmation Number	9086
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)	Fee_Transmittal_Form.PDF	62892 41f9daa0fb8c839c570723040d6537d5da6632b3	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30763 fb8259398d6e44b5a424dff391919464c6fcf662	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	93655		

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.

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.
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2	8109

61060 7590 05/05/2014

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

EXAMINER	
NGUYEN, HOANG V	
ART UNIT	**PAPER NUMBER**
2845	
MAIL DATE	**DELIVERY MODE**
05/05/2014	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.

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

Application No. : 13718348
Applicant : Mumbru
Filing Date : 12/18/2012
Date Mailed : 05/05/2014

NOTICE TO FILE CORRECTED APPLICATION PAPERS

Notice of Allowance Mailed

This application has been accorded an Allowance Date and is being prepared for issuance. The application, however, is incomplete for the reasons below.

Applicant is given two (2) months from the mail date of this Notice within which to respond. This time period for reply is extendable under 37 CFR 1.136(a) for only TWO additional MONTHS.

The informalities requiring correction are indicated in the attachment(s). If the informality pertains to the abstract, specification (including claims) or drawings, the informality must be corrected with an amendment in compliance with 37 CFR 1.121 (or, if the application is a reissue application, 37 CFR 1.173). Such an amendment may be filed after payment of the issue fee if limited to correction of informalities noted herein. See Waiver of 37 CFR 1.312 for Documents Required by the Office of Patent Publication, 1280 Off. Gaz. Patent Office 918 (March 23, 2004). In addition, if the informality is not corrected until after payment of the issue fee, for purposes of 35 U.S.C. 154(b)(1)(iv), "all outstanding requirements" will be considered to have been satisfied when the informality has been corrected. A failure to respond within the above-identified time period will result in the application being ABANDONED.

See attachment(s).

A copy of this notice MUST be returned with the reply. Please address response to "Mail Stop Issue Fee, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450".

/Daxa Patel/
Publication Branch
Office of Data Management
(571) 272-4200

Application No. 13718348

IDENTIFICATION OF SPECIFICATION/DRAWING INCONSISTENCIES

☐ On Page of the specification there is a brief description of FIG. , but the drawings filed do not include a drawing with that designation. Applicant must respond either by supplying the omitted drawing or by amending the specification to remove all references to that drawing.

☒ The drawings filed 05/22/2013 include FIG. 5 (Figs. (A-B)) and 9A, but the specification's brief description of the drawings does not describe a drawing with that designation. Applicant must respond either by amending the specification to add a brief description of that drawing or by correcting the drawings to remove the drawing in question.

☐ Drawings are present in the application and are referred to in the detailed description of the invention, but the specification does not contain a brief description of the drawings as required by 37 CFR 1.74 and 37 CFR 1.77(b)(8).

☐ Page of the specification refers to FIG. , but no drawing with that designation is described in the brief description of the drawings and no drawing with that designation is present in the application. Applicant must respond either by amending the specification to remove all references to that drawing, or by supplying that drawing and amending the specification to add a brief description of it.

☐ OTHER:

☒ COMMENTS:
Specification dated 05/22/2013, page 28 line 1--Figs. (A-B) should read Figs. 5 (A-B).

Thank you

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: May 29, 2014
Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

Docket No. 47005-P040WUSC2
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Joseph Mumbru et al.

Application No.: 13/718,348 Confirmation No.: 8109

Filed: December 18, 2012 Art Unit: 2845

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

Examiner: H. V. Nguyen

AMENDMENT AFTER ALLOWANCE

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

Dear Madam:

INTRODUCTORY COMMENTS

Prior to issuance of the patent and in response to the Notice to File Corrected Application papers mailed May 5, 2014, Applicant respectfully requests entry on this amendment under 37 C.F.R. 1.312 for the above-captioned patent application.

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

Remarks/Arguments begin on page 3 of this paper.

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: May 29, 2014
Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

Docket No. 47005-P040WUSC2
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Joseph Mumbru et al.

Application No.: 13/718,348 Confirmation No.: 8109

Filed: December 18, 2012 Art Unit: 2845

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

Examiner: H. V. Nguyen

AMENDMENT AFTER ALLOWANCE

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

Dear Madam:

INTRODUCTORY COMMENTS

Prior to issuance of the patent and in response to the Notice to File Corrected Application papers mailed May 5, 2014, Applicant respectfully requests entry on this amendment under 37 C.F.R. 1.312 for the above-captioned patent application.

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 amend paragraph at page 28, lines 1-5 as follows:

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

Please amend paragraph at page 28, lines 20-26 as follows:

Figs. 9(A-C) – (Fig. 9A) 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 **(Fig. 9B)** modifying the dimensions of an arm of the mobile antenna; or **(Fig. 9C)** folding an arm of the mobile antenna.

REMARKS

It is submitted that no new matter has been added by the amendments made by this Amendment After Allowance. In the event the U.S. Patent and Trademark Office determines that an extension is required, Applicant petitions for any required relief including extensions of time and authorizes the Commissioner to charge the cost of such petitions and/or other fees due in connection with the filing of this document to Deposit Account No. 23-2426 referencing docket no. 47005-P040WUSC2.

Dated: May 29, 2014

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:	19160714
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	29-MAY-2014
Filing Date:	18-DEC-2012
Time Stamp:	15:50:24
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	Miscellaneous Incoming Letter	47005CorrectedAppPapers.pdf	20349 93a333b7d15264886e5f9913b3b7f5b94f632330	no	1

Warnings:	
Information:	

2	Amendment after Notice of Allowance (Rule 312)	47005AmendmentafterAllowance.pdf	27476 442368d1afd561eb14ecf610f472d8fcd3ce1689	no	3
Warnings:					
Information:					
			Total Files Size (in bytes):	47825	

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 37 CFR § 1.6(a)(4).

Dated: May 29, 2014
Electronic Signature for Shoaib A. Mithani: /Shoaib A. Mithani/

Docket No.: 47005-P040WUSC2
(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Joseph Mumbru et al.

Application No.: 13/718,348 | Confirmation No.: 8109

Filed: December 18, 2012 | Art Unit: 2845

For: HANDHELD DEVICE WITH TWO ANTENNAS, AND METHOD OF ENHANCING THE ISOLATION BETWEEN THE ANTENNAS | Examiner: H. V. Nguyen

RESPONSE TO NOTICE TO FILE CORRECTED APPLICATION PAPERS

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

Dear Madam:

In response to the Notice to File Corrected Application Papers mailed May 5, 2014, Applicant respectfully submits an Amendment After Allowance. No new matter has been added. 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-P040WUSC2.

Dated: May 29, 2014

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

6303322v.1 47005-P040WUSC2

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.
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2	8109

61060 7590 06/02/2014

WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313

EXAMINER	
NGUYEN, HOANG V	
ART UNIT	PAPER NUMBER
2845	
MAIL DATE	DELIVERY MODE
06/02/2014	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.

Response to Rule 312 Communication	Application No.	Applicant(s)
	13/718,348	JOSEPH M.
	Examiner	Art Unit

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address –

1. ☒ The amendment filed on *29 May 2014* under 37 CFR 1.312 has been considered, and has been:

a) ☒ entered.

b) ☐ entered as directed to matters of form not affecting the scope of the invention.

c) ☐ disapproved because the amendment was filed after the payment of the issue fee.
Any amendment filed after the date the issue fee is paid must be accompanied by a petition under 37 CFR 1.313(c)(1) and the required fee to withdraw the application from issue.

d) ☐ disapproved. See explanation below.

e) ☐ entered in part. See explanation below.

B.Crittenden

Publishing Division

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.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/718,348	08/19/2014	8810458	47005-P040WUSC2	8109

61060 7590 07/30/2014

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, Sant Cugat del Valles, SPAIN;
Carles Puente, Sant Cugat del Valles, SPAIN;
FRACTUS, S.A., Sant Cugat del Valles, 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.

Application Number	Application Date	Title	Patent Number	Grant Date	Status	Reel/Frame
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

SCHEDULE A

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:	45303062
Application Number:	13718348
International Application Number:	
Confirmation Number:	8109
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-P040WUSC2
Receipt Date:	23-MAR-2022
Filing Date:	18-DEC-2012
Time Stamp:	18:00:06
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

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.

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
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2

CONFIRMATION NO. 8109

61060
WINSTEAD PC
P.O. BOX 131851
DALLAS, TX 75313-1851

POWER OF ATTORNEY NOTICE

OC000000132707257

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 applicant. 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**.

/dtdinh/

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
13/718,348	12/18/2012	Josep Mumbru	47005-P040WUSC2

CONFIRMATION NO. 8109

27896
EDELL, SHAPIRO & FINNAN, LLC
9801 Washingtonian Blvd.
Suite 750
Gaithersburg, MD 20878

POA ACCEPTANCE LETTER



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**.

/dtdinh/