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(54) Efficient integrated miniature antenna structure for multi-GHz wireless applications

(57) The invention discloses an electronic module (100) comprising at least one substrate made of at least two layers of wiring separated by at least one layer of insulating material. The module further comprises a three-dimensional (3D) antenna structure formed on the at least one substrate out of the at least two layers of wiring and of a plurality of vas electrically connecting the at least two layers of wiring through the at least one layer of insulating material. The module also comprises at least one electronic chip assembled on the substrate to be in contact with at least one of the two layers of wiring, the electronic chip aimed at receiving and/or transmitting radio frequency signals (RF). The electrical characteristics of the 3D antenna structure are tuned to allow the antenna to be directly connected to the electronic chip on the substrate through electrically controlled wiring connections for a wavelength of the signals to be received and/or transmitted by the electronic chip.
The antenna can thus be integrated in the same module as a RE transceiver chip and has performances comparable to the ones of large discrete antennas.
The embodiments show an inverted antenna with folded radiating element and an optional parasitic element.

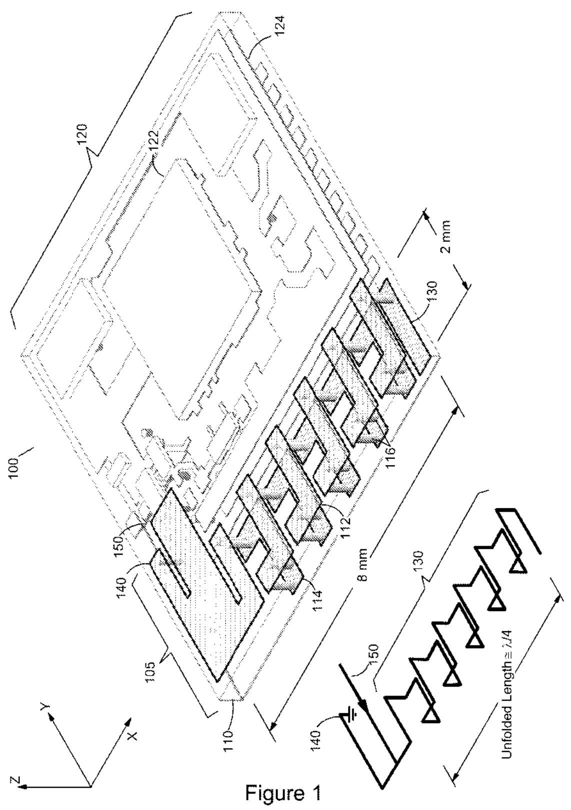

Figure 1

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to the field of antennas and more specifically to miniature antennas of the kind used in electronic portable and handheld devices to receive and transmit signals in a multi gigahertz range.

BACKGROUND OF THE INVENTION

[0002] The proliferation of all sorts of portable and handheld electronic devices in the recent years has been accompanied by the integration in those ubiquitous communications devices of multiple wireless technologies. Indeed, it is not now infrequent that a cellular phone, e.g.: a GSM mobile phone (Global System for Mobile communications) also embeds a Bluetooth™ short range wireless link to connect the phone to another device; typically, to connect to a personal computer or to a mobile headset. Also, recent high-end mobile phones often include a GPS (global positioning system) receiver. And, most of the mobile computers and PDAs (personal digital assistants) are equipped to allow connection to a wireless LAN (local area network), e.g.: a Wi-Fi™ LAN so that to get access to the Internet within buildings and any public areas providing the appropriate wireless access points.

[0003] All these portable and handheld devices must then embed multiple antennas adapted to the various types of wireless technologies supported. It is now common that four or five antennas may have to be implemented in a mobile phone supporting multiple voice and data communications protocols. Because the trend is also in the reduction of the form factor of these devices the chief difficulty is to maintain the performance of those antennas while they must fit in packages that are becoming increasingly smaller and slimmer. Standard handheld devices have now volumes typically in a range of 50 to 100 cm^3; e.g., 5x10x1 cm for the smallest.

[0004] The laws of physics applying to antennas do not however permit a simple corresponding reduction of their sizes just to fit into smaller packages. Reducing antenna sizes without sacrificing performance becomes the main challenge that designers of these versatile communications devices are faced with. For antennas that must operate in a multi gigahertz range (typically, in a 1-5 GHz range) the wavelength remains a significant factor with respect to the overall package size. At 2.5 GHz, wavelength in the air is of 12 cm. Even if good quarter-wavelength antenna design exist, such as the planar inverted F antenna (PIFA) common in cellular phones with built-in antennas, resulting size is still significant for the kind of package sizes considered.

[0005] Also, these antennas must be considered in their tightly constrained environment. RF (radio frequency) noise and other system interactions can undermine antenna performance if not properly accounted for. Especially, the close presence of numerous electronic components and of a printed circuit board (PCB) with a ground plane to hold them may be very detrimental to the good operation of the antennas.

[0006] It is therefore the object of the invention to disclose a miniature antenna design well adapted to the tightly constrained packaging of recent portable and handheld communications devices possibly allowing the integration of multiples antennas into the components without sacrificing their performances for transmitting and receiving RF signals in a few gigahertz range.

[0007] Further objects, features and advantages of the present invention will become apparent to the ones skilled in the art upon examination of the following description in reference to the accompanying drawings. It is intended that any additional advantages be incorporated herein.

SUMMARY OF THE INVENTION

[0008] In view of the above the invention discloses an electronic module comprising at least one substrate made of at least two layers of wiring separated by at least one layer of insulating material. The module further comprises a three-dimensional (3D) antenna structure formed on the at least one substrate out of the at least two layers of wiring and of a plurality of vias electrically connecting the at least two layers of wiring through the at least one layer of insulating material. The module also comprises at least one electronic chip assembled on the substrate to be in contact with at least one of the two layers of wiring, the electronic chip aimed at receiving and/or transmitting radio frequency signals (RF). The electrical characteristics of the 3D antenna structure are tuned to allow the antenna to be directly connected to the electronic chip on the substrate through electrically controlled wiring connections. This is done for a wavelength of the signals to be received and/or transmitted by the electronic chip.

[0009] The 3D antenna structure of the invention may also include, but is not limited to, following characteristics:

- It includes a ground plane to provide a common electrical reference to the at least one electronic chip and to the 3D antenna structure.
- The 3D antenna structure comprises: an open ended radiating element, an intermediate feeding leg and a shorted

ending leg to the ground plane, forming on the substrate a 3D pattern of wiring connections.

- The 3D antenna structure further includes an electromagnetically coupled parasitic leg with an open end and a shorted end to the ground plane.
- The electrical characteristics of the 3D antenna structure are tuned by adjusting geometric dimensions of the 3D pattern of wiring connections electrically and capacitively coupled to form the antenna.
- The electrical characteristics of the 3D antenna structure are further tuned by adjusting distances between the capacitively coupled wiring connections and ground plane participating to the 3D antenna structure.
- The electrical characteristics of the 3D antenna are adjusted by selecting a permittivity for each material used for the at least one layer of insulating material.
- The electrical characteristics of the 3D antenna are tuned to have antenna resonating at quarter wavelength of the signals to be received and/or transmitted.
- The parasitic leg behaves as a second resonator electromagnetically coupled to the antenna and is tuned to increase bandwidth of the 3D antenna structure.
- The open ended radiating element includes a plurality of L-shaped conducting traces alternatively situated on the at least two wiring layers and serially connected at each end by at least one interlayer via.
- The electrical characteristics of the 3D antenna are tuned to be adapted to the characteristic impedance of the controlled wiring connections on the substrate.
- The geometric dimensions of the 3D pattern of wiring connections and distances between the capacitively coupled wiring connections and ground plane participating to the 3D antenna structure are adjusted to minimize influence of the environment in which the electronic module is operated.

[0010] The invention further discloses a communications device including an electronic module as described in the present specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Figure 1 shows an exemplary embodiment of an antenna structure according to the invention.
Figure 2 discusses how the geometric and physical characteristics of the antenna are tuned to be adapted to the wavelength of the signals to receive and transmit.
Figure 3 shows an alternate embodiment of the antenna structure including a parasitic leg.
Figure 4 shows simulation data and measured experimental results.
Figure 5 shows the radiation pattern obtained with the antenna structure of the invention.

DETAILED DESCRIPTION

[0012] The following detailed description of the invention refers to the accompanying drawings. While the description includes exemplary embodiments, other embodiments are possible, and changes may be made to the embodiments described without departing from the spirit and scope of the invention.

[0013] Figure 1 shows an exemplary embodiment of an antenna (105) according to the invention.

[0014] This kind of antenna is destined to be embedded in the same package as the RF front-end module aimed at receiving and transmitting signals for any of the multiple wireless technologies implemented in today's handheld and portable devices. Wireless technologies such as the ones discussed in the background section typically operate in a range of 1 to 5 GHz, i.e., at centimeter wavelengths, from 6 to 30 cm. The antenna takes advantage of the multilayered substrate (110) of the package in which it is embedded and having at least a top and a bottom wiring layer. The substrate is, e.g., a ceramic substrate such as the ones produced with the low-temperature co-fired ceramic technology or LTCC. The ceramic substrate is then used to house, in a single module (100), the various chips and other electronic components (120) needed to implement all modern communications devices. The high level of integration thus achieved is actually required to implement all the functions carried out by the handheld and portable devices having to fit into the smallest packages (50 to 100 cm3 as discussed in the background section). Typically, such an electronic chip is a low noise amplifier (LNA) and RF receiver which can thus be advantageously directly connected through controlled substrate conductive traces to the antenna without the requirement of having to interpose any adaptation circuitry as it is most often the case when a discrete separate antenna is used. Discrete antenna which needs instead to be placed on, or connected to, the printed circuit board (PCB) supporting all the electronic components of any standard handheld or portable device. Materials of PCBs such as the ones used in low-cost cellular phones have however not necessarily the best possible RF electrical characteristics for the high frequencies considered (1-5 GHz). Also, loose tolerances of the geometric dimensions, e.g., the width of the printed conductive traces and thickness of the insulating layers may introduce significant dispersion of the electrical characteristics. Hence, mediocre PCB RF characteristics and the need of an adaptation circuitry do not contribute to simply reach the level of performance and high sensitivity required for the RF front end circuitry of standard communications devices on the contrary of what invention can do by integrating the antenna into the RF front-end module where materials and dimensions are more tightly controlled.

[0015] Also, integration of the antenna into the same module as the RF front-end circuitry greatly facilitates the overall design of the box and /or mother card in which they are integrated (no critical RF designer skill is actually needed). Manufacturing is also facilitated since there are no longer any discrete RF components to carefully place and assemble at the expense of obtaining degraded performances if just slightly misplaced. This allows a higher level of automation and avoids having recourse to skilled professionals to manually assemble and check them.

[0016] Embedding an efficient antenna into a small module of the kind used in handheld and portable devices is however all but straightforward. For the range of centimeter wavelengths considered (6-30) the size of the module in which the antenna must be integrated is definitively a problem. Handheld and portable devices use low profile packages (1 mm or less) such as the ones referred to as quad flat no-lead (QFN) modules whose overall external size is a square not exceeding 9x9 mm for the largest. If constant progress have always been achieved over the years (following Moore's law) allowing the integration of an ever growing number of semiconductor elements on small electronic chips that can easily fit into this kind of package (so that any complex electronic function, such as a GHz RF transceiver, can be readily carried out) the integration of an antenna does not follow this trend since the laws of physics applying to this particular device derive from the wavelength at which they must receive and transmit signals as discussed in the background section.

[0017] The invention manages to overcome the discrepancy that exists between the dimension of the module housing the RF front-end circuitry (less than 1cm) and the multi-centimeter wavelength signals that the integrated antenna must be able to receive and transmit. This is achieved by the invention which implements on the multilayered substrate of the module, out of multiple top and bottom conductive traces (112, 114) and interlayer vias (116), a folded three-dimensional (3D) miniature antenna an example of which is depicted on Figure 1. In this particular example the substrate also comprises an intermediate ground plane (124) in the area housing the electronic components to provide a good common electrical reference to these components and to connect the shorted end (140) of the antenna structure. The presence of a ground plane also allow the implementation of conductive traces with better controlled RF electrical characteristics, generally devised to have a characteristic impedance close to 50 Ohms that must match which the one of antenna to prevent reflections from occurring.

[0018] Figure 1 more specifically illustrates the integration of an antenna devised to operate at 2.5 GHz, in the middle of the frequency range considered, i.e., for a wavelength of 12 cm in free space. The antenna is devised to resonate at quarter wavelength ($\lambda/4$). Unfolded, the 3D radiating structure that would be 3 cm long in free space is actually close to 2.6 cm in this particular embodiment taken into consideration the actual permittivity (higher than the one of free space) of the material used for the insulating layers and of the dielectric materials of the surrounding components. The antenna has an open ended radiating element (130) and a shorted end (140) to the ground of the module. It is fed through an intermediate leg (150) close to the shorted end. The overall size of this particular antenna is about 2mm by 8mm. It occupies roughly only one-fifth to one-fourth of the total useable module area. The remaining space is used to house all the other electronic components needed to implement the device functions including the RF transceiver (122) that drives the antenna.

[0019] Figure 2 discusses how the geometric and physical characteristics of the antenna are tuned to be adapted to the wavelength of the signals to receive and transmit and to the electrical characteristics of the module substrate so that a RF transceiver can be connected directly to the antenna without any adaptation circuitry that would otherwise impair the reception and transmission of signals, i.e., the reception sensitivity and transmission efficiency of the system.

[0020] The main geometric parameters that control the antenna pattern, thus eventually its electrical characteristics, are shown in Figure 2. Among all these geometric parameters including length (236) and width (238) of the 3D structure, parameter d (202) is the depth difference between the two slits (204, 206) separating the feeding leg (250) of the antenna from its shorted end (240) on one side and from the open-ended radiating element on the other side (230). It strongly affects S11, one parameter of the so-called scattering parameters (S-parameters) that are commonly used to measure and qualify the behaving of linear passive or active circuits operating at radio frequencies. S-parameters are used to evaluate electrical properties of these circuits such as their gain, return loss, voltage standing wave ratio (VSWR). In a 2-port circuit, S11, one of four possible S-parameters in a 2x2 matrix, measures the input port voltage reflection coefficient. It is generally expressed in decibel (dB) and characterizes the return loss relative to reference impedance. The lower the value of S11 the better the matching between the antenna and the transceiver is achieved. Following table shows values obtained with antenna structure of the invention for a width of the radiating element traces (wp) set at 0.2 mm. Geometric parameter d also slightly affects the resonance frequency of the antenna.

for wp = 0,2 mm

d (mm)	S11 (dB)	Resonance (GHz)
1.2	-16	2.42
1.0	-35	2.46
0.8	-12	2.48
0.6	-5	2.50
0.4	-2.3	2.52

[0021] The resonance frequency of the antenna is more affected by the height of the interlayer vias set by the thickness *t* (234) of the insulating one or more layers separating the top and bottom conductive layers from which the 3D antenna structure is formed.

t (mm)	Resonance (GHz)
0.8	2.36
0.7	2.42
0.6	2.45
0.5	2.48
0.4	2.53
0.3	2.61
0.2	2.70
0.1	2.80

[0022] The width of the conductive traces forming the 3D radiating element, i.e.: *wp* (232) affects significantly all the electrical parameters of the antenna as shown in table hereafter. Radiation efficiency is the ratio between the power actually radiated by the antenna versus the one injected by the transceiver through the feeding leg (250). The difference contributes to the heat that must be dissipated by the module. Obviously, the closer to 100% this value the better it is.

wp (mm)	Resonance (GHz)	S11 (dB)	Bandwidth (MHz)	Bandwidth %	Efficiency %
0.5	2.49	-19.4	61	2.4	52.1
0.4	2.53	-26.6	60	2.4	50.0
0.3	2.51	-30.6	54	2.2	52.6
0.2	2.45	-18.8	44	1.8	47.4
0.1	2.32	-12.2	24	1.0	38.9

[0023] The permittivity of the insulating material forming the substrate also contributes to modify the electrical characteristics of the antenna. Permittivity is generally expressed relatively to the one of free space (εr). For an antenna whose pattern and dimensions are fixed if a material with a higher permittivity is chosen the resonance frequency of the antenna will be lower. Hence, for a given frequency the size of the antenna will be reduced accordingly. In other words, the speed of propagation of the signals and their wavelengths are lowered. If this well-known mechanism has actually been used to allow the implementation of small antennas this does not go without degrading other electrical characteristics because of higher losses in the higher-permittivity material of which substrate is made.

[0024] The above figures and behaving of the antenna in general can be simulated prior to actual implementation with any of a few commercially available specialized software products. The variations of all the above mentioned geometric and physical parameters have thus been thoroughly verified. Because this kind of antennas is destined to fit in the tightly constrained environment of small handheld and portable devices it is important to notice that the close environment of the antenna has been carefully taken into account too. This is particularly the case of the ground plane (224) of module and PCB. A best possible tradeoff has been determined that have led to the antenna structure of the invention as depicted in Figure 1 and 2. This structure has shown to be fairly insensitive to its close environment. The parasitic leg described hereafter in Figure 3 which enhances the bandwidth of the antenna contributes to render the 3D structure less sensitive to its close environment.

[0025] Figure 3 shows an alternate embodiment of the antenna structure of the invention including a parasitic leg.

[0026] Using the multilayered structure of the substrate, the folded parasitic leg (370) is placed in close proximity of the main antenna structure previously described without being electrically connected to it though. Like the main structure, one end of the parasitic leg has an open end (374) and a shorted end (372) to the ground plane of the module. The main structure of the antenna and the parasitic leg are thus electromagnetically coupled through the dielectric material of the substrate. The chief objective of the parasitic leg is to obtain a second resonance of the whole antenna structure, close to the main one, so as to increase the bandwidth of the antenna as illustrated (420) in Figure 4 hereafter.

[0027] Figure 4 shows simulation data and measured experimental results.

[0028] The upper chart (410) compares the simulated and measured S11 parameter discussed in Figure 2 for a particular implementation of the antenna structure of Figure 1. There is a pretty good agreement between simulated and measured figures. S11 parameter is below -35 dB which corresponds to the best result shown in previous tables.

[0029] The middle chart (420) shows the effect of placing a parasitic leg close to the main antenna structure as discussed in Figure 3. The bandwidth is significantly widened (422) and reaches a value close to 100 MHz at -10 dB due to a second close resonance induced by the presence of the electromagnetically coupled parasitic leg with the main antenna structure.

[0030] The lower chart (430) shows the level of signal measured in dBm (attenuation in decibel versus a reference 1mWatt signal) for an integrated antenna structure according to the invention. The measured signal is an actual WiFi signal broadcasted in a confined area. For comparison, in the same conditions, the broadcasted signal is measured with a standard dipole (several cm high) of the kind mounted on wireless boxes such as a wireless router. In spite of the large difference between antenna sizes the level of reception are comparable (432). The standard dipole is just slightly better.

[0031] Figure 5 shows the radiation pattern obtained with the antenna structure of the invention. The three diagrams, which plot the gain in dB of the antenna (i.e.: the ratio between the power radiated in a given direction to the power that would be radiated by a reference isotropic antenna), illustrates the fact that an antenna according to the invention is indeed radiating in all directions of all planes.

Claims

1. An electronic module (100) comprising at least one substrate (110) having at least two layers of wiring separated by at least one layer of insulating material and at least one electronic chip (122) assembled on the substrate in contact with at least one of the two layers of wiring, the electronic chip aimed at receiving and/or transmitting radio frequency signals, the electronic module **characterized in that** it comprises;
a three-dimensional antenna structure formed on the at least one substrate out of the at least two layers of wiring (112, 114) and of a plurality of interlayer vias (116) electrically connecting the at least two layers of wiring through the at least one layer of insulating material.

2. The electronic module of claim 1 wherein the electrical characteristics of the three-dimensional antenna structure are tuned to allow the antenna to be directly connected to the electronic chip on the substrate through electrically controlled wiring connections for a wavelength of the signals to be received and/or transmitted by the electronic chip.

3. The electronic module of claim 1 or claim 2 wherein the substrate includes a ground plane (124, 224) to provide a common electrical reference to the at least one electronic chip and to the three-dimensional antenna structure.

4. The electronic module of claim 3 wherein the three-dimensional antenna structure comprises: an open ended radiating element (130, 230), an intermediate feeding leg (150, 250) and a shorted ending leg (140, 240) to the ground plane, forming on the substrate a three-dimensional pattern of wiring connections.

5. The electronic module of claim 4 wherein the three-dimensional antenna structure further includes an electromagnetically coupled parasitic leg (370) with an open end and a shorted end (372) to the ground plane.

6. The electronic module of claim 5 wherein the electrical characteristics of the three-dimensional antenna structure are tuned by adjusting geometric dimensions of the three-dimensional pattern of wiring connections electrically and

capacitively coupled to form the three-dimensional antenna structure (202, 204,206,230,232,234,236,238,240,250,370,372,374).

7. The electronic module of claim 6 wherein the electrical characteristics of the three-dimensional antenna structure are further tuned by adjusting distances between the capacitively coupled wiring connections and ground plane participating to the three-dimensional antenna structure.

8. The electronic module of claim 7 wherein the electrical characteristics of the three-dimensional antenna structure are adjusted by selecting a permittivity for each material used for the at least one layer of insulating material.

9. The electronic module of any of claims 5 to 8 wherein the parasitic leg is tuned to increase bandwidth of the three-dimensional antenna structure (420).

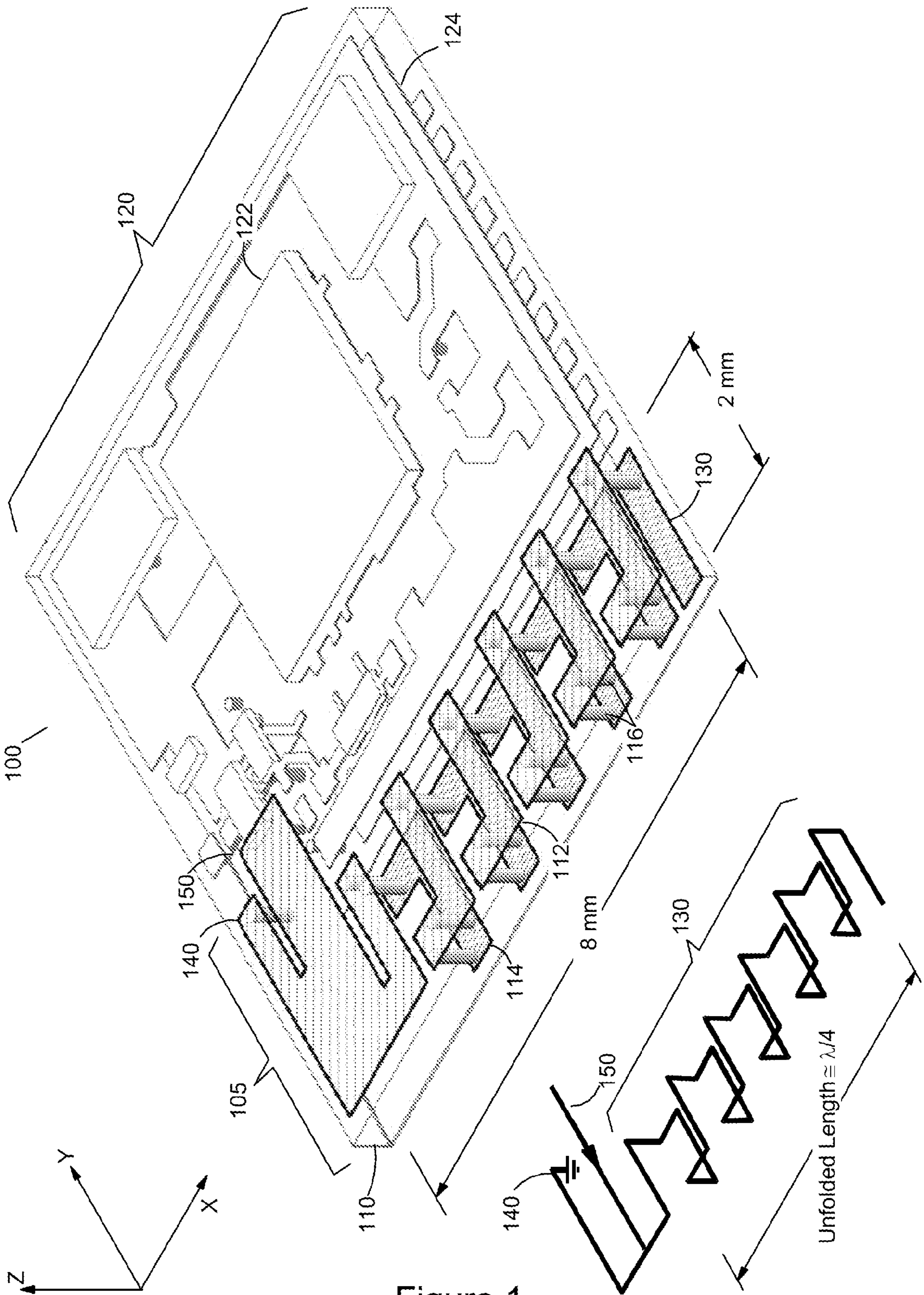
10. The electronic module of any of claims 4 to 9 wherein the open ended radiating element includes a plurality of L-shaped conducting traces (112, 114) alternatively situated on the at least two wiring layers and serially connected at each end by at least one interlayer via (116).

11. The electronic module of any one of previous claims wherein the electrical characteristics of the three-dimensional antenna structure are tuned to have antenna resonating at quarter wavelength of the signals to be received and/or transmitted.

12. The electronic module of any one of previous claims wherein the electrical characteristics of the three-dimensional antenna structure are tuned to be adapted to the characteristic impedance of the controlled wiring connections on the substrate.

13. The electronic module of any one of previous claims wherein geometric dimensions of the three-dimensional pattern of wiring connections and distances between the capacitively coupled wiring connections and ground plane participating to the three-dimensional antenna structure are adjusted to minimize influence of the environment in which the electronic module is operated.

14. A communications device including an electronic module according to any one of claims 1 to 13.



100
120
122
124
2 mm
130
116
112
8 mm
114
150
140
105
110
Y
X
Z
130
150
140
Unfolded Length ≅ λ/4

Figure 1

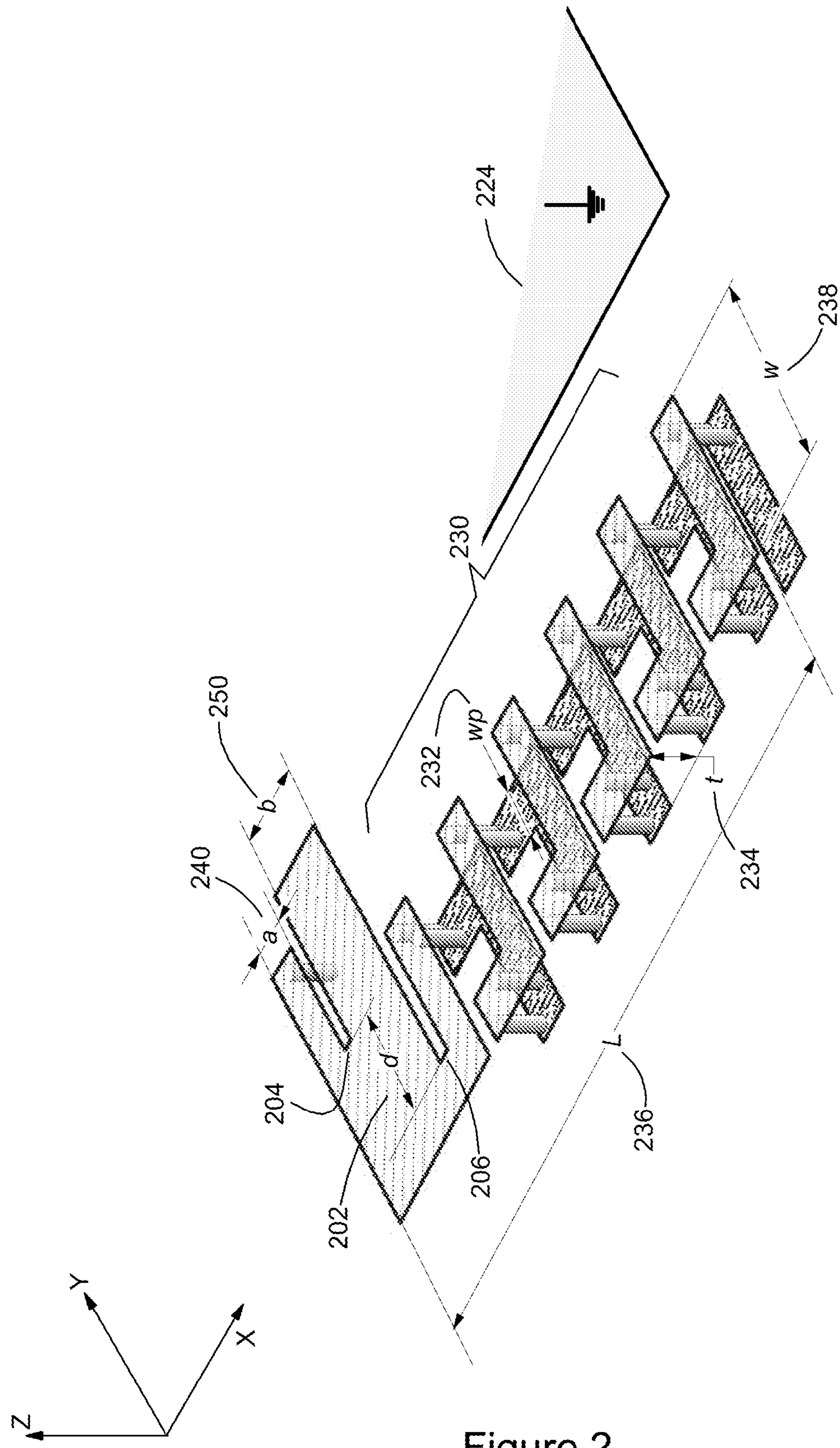


Figure 2

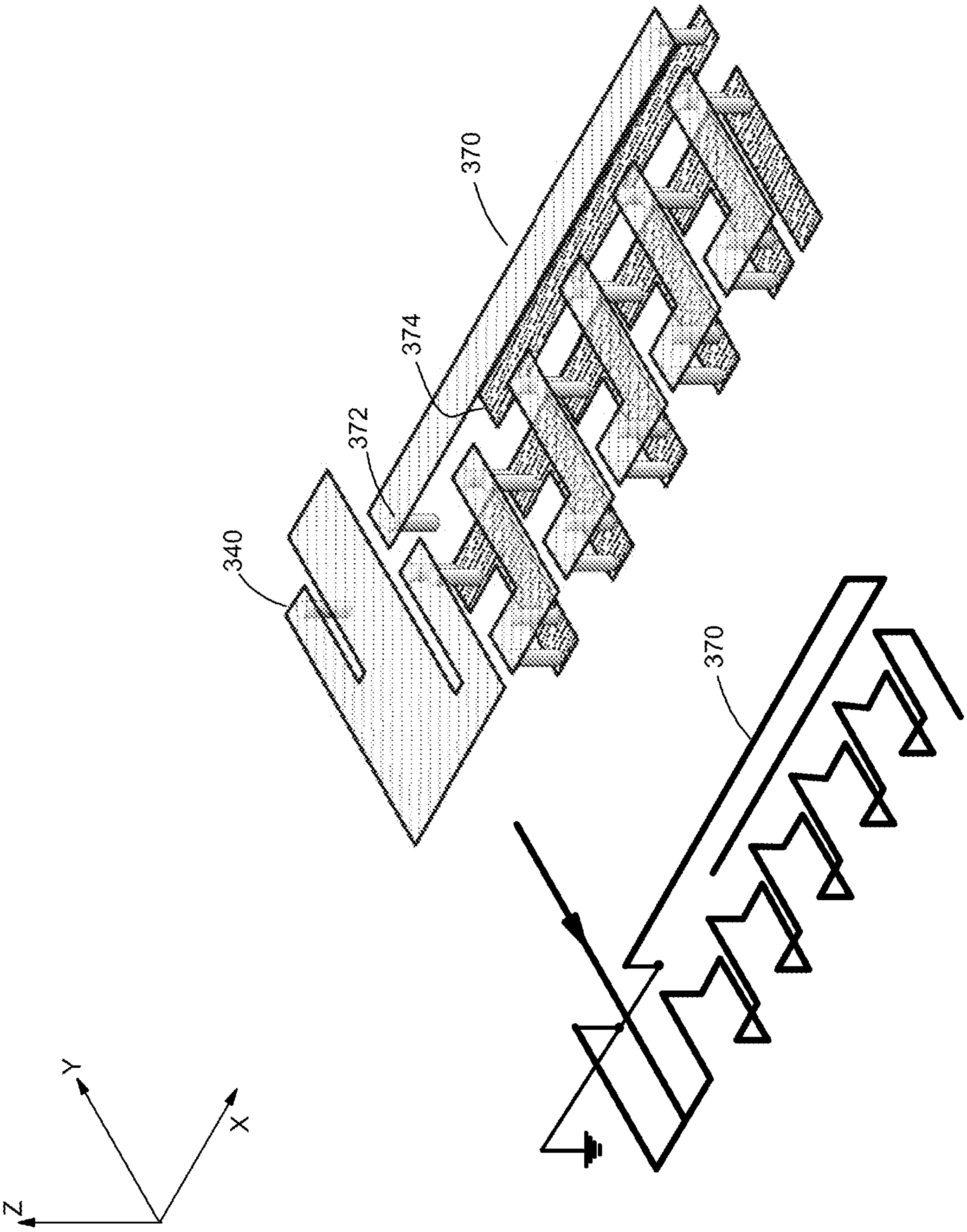


Figure 3

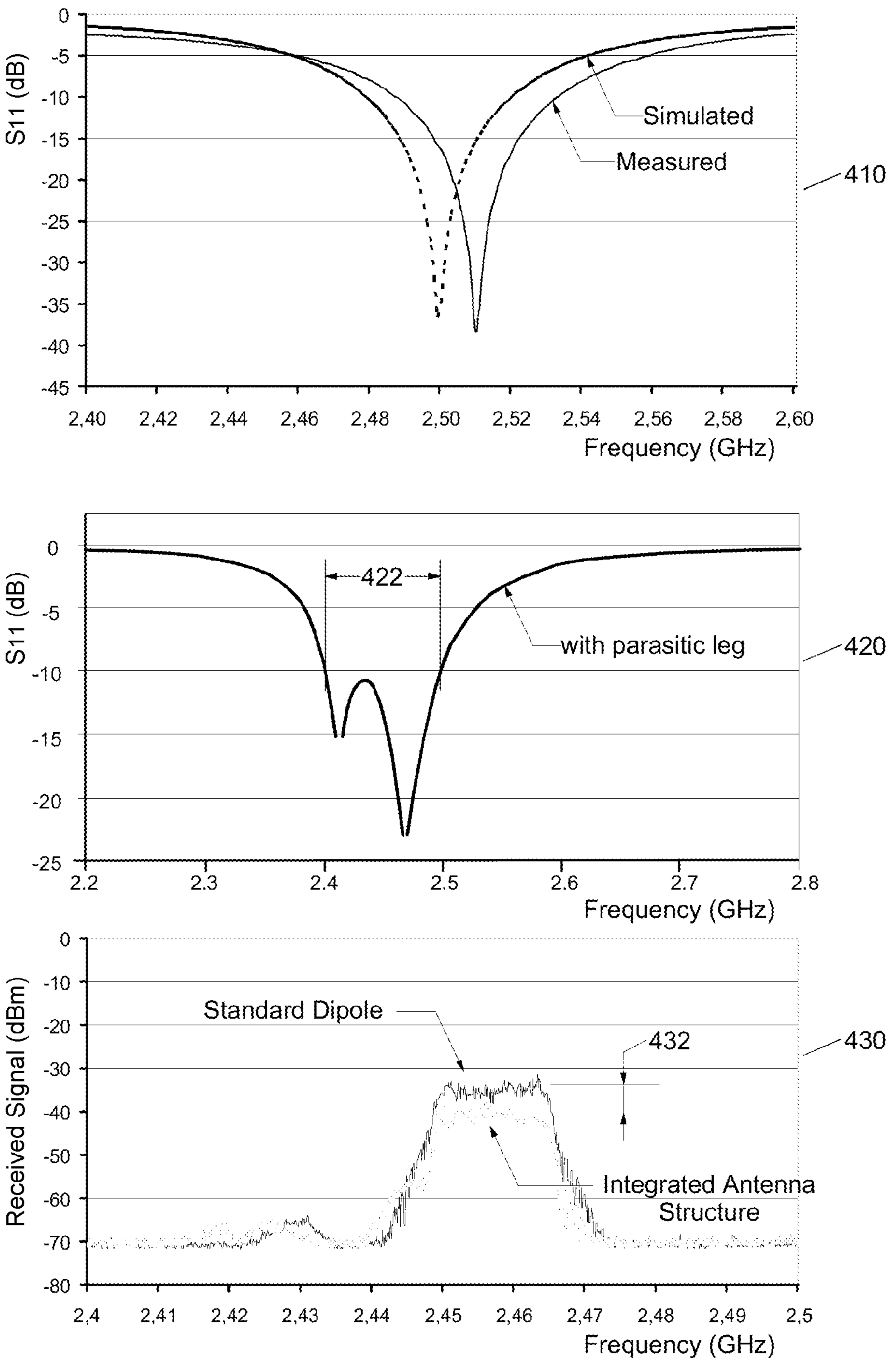

0
-5
-10
-15
-20
-25
-30
-35
-40
-45
S11 (dB)
2,40 2,42 2,44 2,46 2,48 2,50 2,52 2,54 2,56 2,58 2,60
Frequency (GHz)
Simulated
Measured
410
0
-5
-10
-15
-20
-25
S11 (dB)
422
with parasitic leg
420
2.2 2.3 2.4 2.5 2.6 2.7 2.8
Frequency (GHz)
0
-10
-20
-30
-40
-50
-60
-70
-80
Received Signal (dBm)
Standard Dipole
432
430
Integrated Antenna Structure
2,4 2,41 2,42 2,43 2,44 2,45 2,46 2,47 2,48 2,49 2,5
Frequency (GHz)

Figure 4

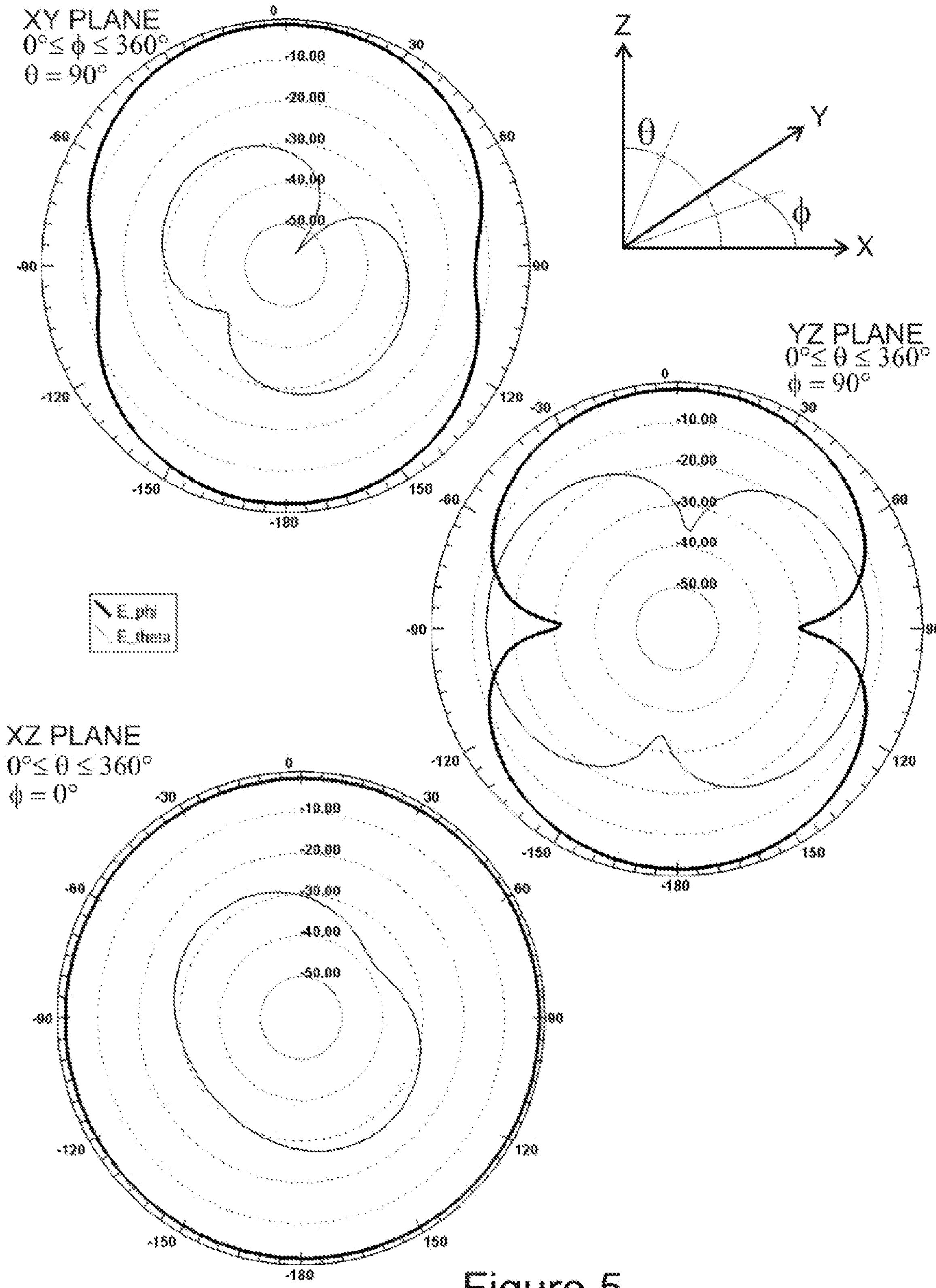

XY PLANE
0°≤ ϕ ≤ 360°
θ = 90°
YZ PLANE
0°≤ θ ≤ 360°
ϕ = 90°
XZ PLANE
0°≤ θ ≤ 360°
ϕ = 0°
Z
Y
X
θ
ϕ
E_phi
E_theta
-10.00
-20.00
-30.00
-40.00
-50.00
0
30
60
90
120
150
-180
-150
-120
-90
-60
-30

Figure 5

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EUROPEAN SEARCH REPORT

Application Number
EP 09 30 5581

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2007/279879 A1 (FUJII TOMOHARU [JP]) 6 December 2007 (2007-12-06) * paragraph [0053] - paragraph [0055] * * paragraph [0057] * * paragraph [0069] - paragraph [0071] * * paragraph [0078] * * paragraph [0128] * * figures 4-6 *	1-4,6-9, 11-14	INV. H01Q1/24 H01Q1/38 H01Q9/42
Y	see above	5,10	
Y	WO 01/63690 A (ERICSSON TELEFON AB L M [SE]; DAHLSTROEM ANDERS [SE]; EGOROV IGOR [SE]) 30 August 2001 (2001-08-30) * page 5, lines 19-25 * * page 6, lines 15-26 * * page 7, lines 15-19 * * figures 4,5 *	5	
A	see above	6-9,11, 12	
Y	US 2003/227411 A1 (KIM HYUN HAK [KR] ET AL) 11 December 2003 (2003-12-11) * paragraph [0013] * * paragraph [0042] * * paragraph [0044] * * paragraphs [0046], [0047] * * figures 6-8 *	5,10	TECHNICAL FIELDS SEARCHED (IPC) H01Q
Y	US 2006/145928 A1 (LEE JAE C [KR] LEE JAE CHAN [KR]) 6 July 2006 (2006-07-06) * paragraphs [0032] - [0034] * * paragraph [0043] * * figures 1-3 *	10	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	27 August 2009	Köppe, Maro

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CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
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EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	27 August 2009	Köppe, Maro

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
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