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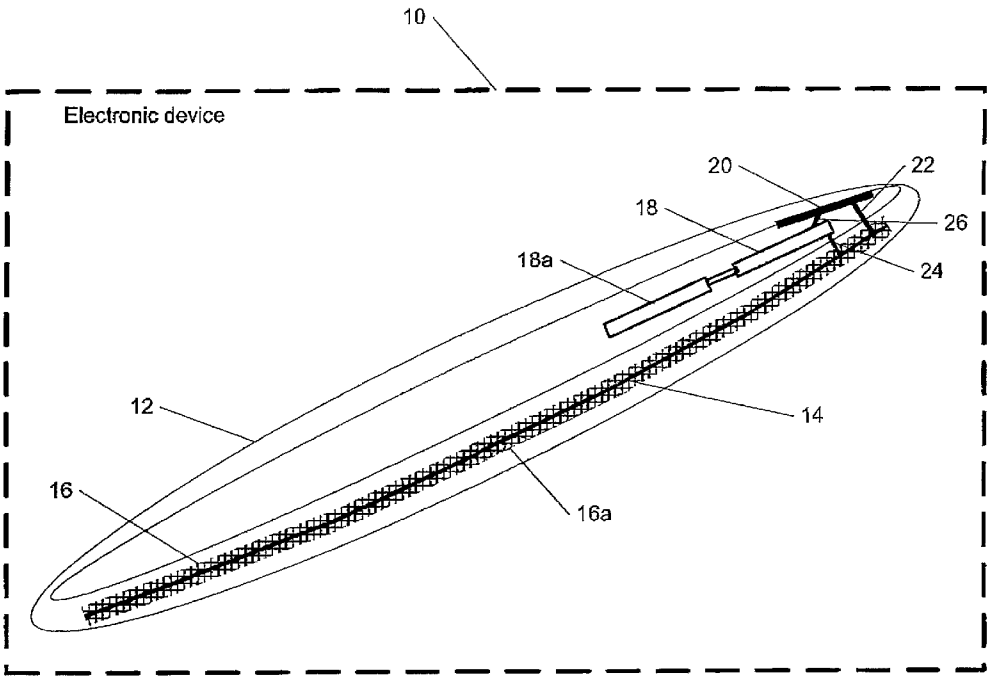
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(54) Title: MAGNETIC MATERIAL IN ANTENNA GROUND



(57) Abstract: The specification and drawings present a new method and apparatus for improving performance of antennas used in wireless communications by using magnetic materials in a ground plane, e.g., by disposing a layer of a magnetic material on a ground plate and, furthermore, by embedding the ground plate with the disposed magnetic material inside of one or more parts of an electronic device.

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MAGNETIC MATERIAL IN ANTENNA GROUND

Field of the Invention

This invention generally relates to wireless communications and more specifically to improving performance of antennas used in wireless communications.

Background Art

Antennas are critical elements in mobile products and their number is increasing with required wireless access in one wireless product using a small space. Typically, an antenna and a ground plane in such a wireless product require certain space for avoiding electromagnetic interactions. Size and type of the antenna itself is determined by a frequency of a radio system and/or by the required bandwidth of the antenna solution. Specifically, in case of resonating antennas, their distance to the ground must be large enough for a proper performance, e.g., by providing more than 2 mm distance as a certain minimum required space (in the wireless product). Generally, this distance to the ground plane can be more or less than 2 mm depending on operating frequency, bandwidth considerations and on antenna type as well (e.g. Dipole, PIFA, Patch, etc).

PIFA/PILA (Planar Inverted F-Antenna/ Planar Inverted L-Antenna) antennas are widely used in small portable products due to their simplicity, size and flexibility in design. There are several methods to miniaturize the size of these antennas:

- using dielectric materials between antenna elements and the ground,
- forming and dimensioning radiating/antenna elements in a proper way,
- forming and dimensioning the ground planes by taking into account functionalities of other components, like cameras, located in a vicinity of the antenna elements, etc. It is also determined by the required bandwidth of the antenna solution electronics is becoming smaller and possibly limited by other functional elements like camera, display etc. needed in a product, simultaneously the ground plane for the PIFA/PILA antenna will become smaller and non-uniform or divided into many parts. As a result, the design and functionality of this type (PIFA/PILA) of antennas will suffer. Different form factors of the portable products may also require splitting the electronics into many parts according to the shape and space available and dividing

also the ground plane into small pieces. Ideally PIFA/PILA type antennas work at their best if the ground plane is infinite. In practice this is not possible. However it is known, for example, that the ground plane size (e.g., for a square in this example) for the PIFA antenna should be more than (0.2 * wavelength)^2 for 2 GHz resonating antennas and the ground plane size (for the square in this example) should be equal or more than (0.8* wavelength)^2 to get the maximum bandwidth out as discussed by M.-C. Huynh, W. Stutzman, "Ground Plane Effects on Planar Inverted-F Antenna (PIFA) Performance" in IEE Proc.-Microw. Antennas Propag. Vol. 150, No. 4, August 2003, p. 209 – 213. Because of the direction towards more broadband antennas, for minimizing the number of antenna elements in one product and minimizing the overall space required, it is necessary to guarantee the size of the ground plane seeing by the PIFA/PILA antenna elements.

In case of large enough electronic motherboards in a portable product it is guaranteed that the ground plane for the antennas will be large enough for the operation of PIFA/PILA type antennas. In small space/products it is possible to add capacitance to the ground and extend the size of the ground plane by changing the ground impedance when the space is limited for the physical size of the ground plane. These approaches are relying on nearly uniform and as large size as possible electronics including the ground plane implementation within the given space. It is also known that by adding dielectric layer with high dielectric constant between antenna elements and the ground plane it is possible to reduce the size of the antenna system. However, ceramic materials are heavy, brittle and hard to include/embed or integrate. It is further known that placing magnetic material on PIFA antenna elements covering whole or part of the antenna element and/or a feed or a grounding pin where current density is at highest, it is possible without significantly sacrificing (e.g., by a few percents) the antenna bandwidth to reduce antenna volume several tens of percents or even reduce the required volume by a factor of two compared to the implementation where the magnetic material is not used on top of PILA/PIFA element or/and surrounding antenna feed/ground pin, e.g., see Tanaka et al., A Study on Miniaturization of a Handset Antenna Utilizing Magnetic Materials, 10th Asia-Pacific Conference on Communications and the 5th International Symposium on Multi-Dimensional Mobile Communications, p. 665 – 669.

Other antenna types are also affected by the ground plane size, orientation and implementation in situ. These other antennas can be (but are not limited to): monopoles, dipoles, antenna arrays, loops, inverted-F Antennas (IFAs), patch antennas, etc.

Disclosure of the Invention

According to a first aspect of the invention, an apparatus, comprises: an antenna; at least one electronic module electrically coupled to the antenna, for operating the antenna; and a ground plate, electrically coupled to the antenna and to the at least one electronic module, wherein a magnetic material is disposed on the ground plate.

According further to the first aspect of the invention, the magnetic material may be disposed on one surface of the ground plate.

According further to the first aspect of the invention, the magnetic material may be disposed on both surfaces of the ground plate.

Still further according to the first aspect of the invention, the at least one surface of the ground may be completely covered by the magnetic material.

According further to the first aspect of the invention, the at least one surface of the ground may be partially covered by the magnetic material.

According still further to the first aspect of the invention, the ground plate with the disposed magnetic material may be embedded inside of or attached to at least one part of the apparatus comprising or adjacent to the antenna. Further, the at least one part may be a cover of the apparatus.

According further still to the first aspect of the invention, the antenna may comprise one or more antenna elements embedded inside of at least one part of the apparatus, the one or more antenna elements being electrically coupled to the ground plate.

According yet further still to the first aspect of the invention, the at least one electronic module may be embedded inside of at least one part of the apparatus.

Yet still further according to the first aspect of the invention, the at least one electronic module may comprise two or more electronic modules embedded in one or more parts of the apparatus.

Still yet further according to the first aspect of the invention, the ground plate with the disposed magnetic material may be embedded inside of or attached to two or more parts of the apparatus.

Still further still according to the first aspect of the invention, the antenna may be at least one of: a) a planar antenna, b) a planar inverted F-antenna, and c) a planar inverted L-antenna.

According further still to the first aspect of the invention, the antenna may be a non-planar antenna.

According yet further still to the first aspect of the invention, the ground plate may be metallic.

Still according yet further to the first aspect of the invention, the magnetic material may be a layer of a ferromagnetic material.

Yet further still according to the first aspect of the invention, the magnetic material may cover at least one of: a) the antenna, and b) a feed pin coupling the antenna to the at least an electronic module, and c) a grounding pin coupling the antenna to the ground plate.

According to a second aspect of the invention, a method, comprises: disposing a magnetic material on a ground plate electrically coupled to an antenna; and electrically coupling at least one electronic module with the antenna and with the ground plate for operating the antenna.

According further to the second aspect of the invention, the magnetic material may be disposed completely or partially on one surface or on both surfaces of the ground plate.

Further according to the second aspect of the invention, the method may further comprise: embedding the ground plate with the disposed magnetic material inside of or attached to at least one part of the apparatus comprising or adjacent to the antenna.

Still further according to the second aspect of the invention, the at least one electronic module may be embedded inside of the at least one part.

According further to the second aspect of the invention, the method may further comprise: embedding the ground plate with the disposed magnetic material inside of or attached to two or more parts of the apparatus.

According still further to the second aspect of the invention, the magnetic material may be a layer of a ferromagnetic material.

According to a third aspect of the invention, an apparatus, comprises: means for receiving and transmitting an electromagnetic signal; and means comprising a magnetic material for providing a ground which is electrically coupled to the means for receiving and transmitting the electromagnetic signal and to at least one electronic module for operating the means for receiving and transmitting the electromagnetic signal.

Further according to the third aspect of the invention, the means for receiving and transmitting an electromagnetic signal may be an antenna.

Brief Description of the Drawings

For a better understanding of the nature and objects of the present invention, reference is made to the following detailed description taken in conjunction with the following drawings, in which:

Figure 1 is a cross section of an embedded antenna inside of a part of an electronic device with a ground plate totally covered by a magnetic material, according to an embodiment of the present invention;

Figure 2 is a cross section of an embedded antenna inside of a part of an electronic device with a ground plate covered by a magnetic material on one side and with an electronic module also embedded inside that part, according to an embodiment of the present invention;

Figure 3 is a cross section of an embedded antenna inside of a part of an electronic device with a ground plate covered by a magnetic material on one side and with an electronic module also embedded inside that part, wherein the ground plate is an outmost layer of that part, according to an embodiment of the present invention; and

Figure 4 is a cross section of an embedded antenna inside of an electronic device demonstrating a concept, wherein one or more ground plates covered with magnetic material are embedded in multiple parts of an electronic device, according to an embodiment of the present invention.

Modes for Carrying Out the Invention

A new apparatus and method are presented for improving performance of antennas used in wireless communications by using magnetic materials in a ground plane, e.g., by disposing a layer of a magnetic material on a ground plate and furthermore by embedding the ground plate with the disposed magnetic material inside of one or more parts of an apparatus (e.g., a an electronic device, a communication device, a wireless communication device, a portable electronic device, a mobile electronic device, a mobile phone, etc.).

The electromagnetic (EM) waves are slowed in magnetic materials with high permeability and these magnetic materials can be used, according to embodiments of the present invention, to stabilize high current densities generated by EM radiation in the ground plane (or ground plate) of the electronic device. Then a layered antenna ground is plated totally or partially with the magnetic material for relaxing highest current densities on the antenna ground. Furthermore, by embedding the ground with the magnetic material inside of the one or more parts of a communication device as part of its mechanics, can provide maximum ground for an antenna system, according to an embodiment of the present invention.

More specifically, because the performance of multimode (satisfying multiple RF frequency band/system requirements) PIFA/PILA (Planar Inverted F-Antenna/ Planar Inverted L-Antenna) systems is highly dependent on a large enough ground plane and in some cases the ground plane can take part or even be the primary source for the required RF radiation at certain frequencies. Therefore, it is possible to plate or cover partially or totally the ground plane (one or more ground plates) of the antenna system, according to embodiments of the present invention. For maximizing the size of the ground plane for the antenna system, a uniform metal/metallic plate (for the ground) or several of those connected in series can be embedded inside, e.g., a product cover or mechanics of the space where antenna system is located. These two approaches (plating the ground metallic plate/plates with magnetic material partially or totally and embedding the ground plane/-s inside the product cover) can guarantee minimum space and simultaneously uniform and maximized ground plane for the antenna system. Also this approach, according to an embodiment of the present

invention, is not dependent on how many pieces the rest of the electronics is needed to be divided to.

Using the ground plane to cover the maximum of the available product cover, makes antenna design easier and more effective. By adding magnetic layer towards a direction for human body, it is also possible to reduce SAR (specific absorption rate), i.e., to reduce interaction between a user body and the ground plane where the antenna currents flow for minimizing changes in antenna performance (impedance, bandwidth, radiation, etc.) caused by this interaction.

According to embodiments of the present invention, high permeability (typically with permeability of more than 4) magnetic materials can be used, e.g., NiFe, NiFeMo, NiFeCo, FeCoB, etc. The new magnetic materials are developing rapidly towards higher frequencies (> 500 MHz) and different plating methods for magnetic materials are also developing fast. Additionally, an injection molding (IML) which is widely used for high volume product mechanics manufacturing is developing to include electronics, displays etc. When embedding the ground of the antenna system inside mechanics, it is possible to keep mechanics still thin.

According to an embodiment of the present invention, the apparatus (e.g., a communication device) can comprise an antenna, an electronic module electrically coupled to the antenna (for operating the antenna) and a ground plate (typically metallic), electrically coupled to the antenna and to the electronic module, wherein a magnetic material is disposed on the ground plate. The coupling to the ground plate can be direct (e.g., by physically connecting), through components (e.g., capacitors, inductors, resistors) or indirect, e.g., electromagnetic coupling using non-galvanic methods.

According to further embodiments of the present invention, the magnetic material can be disposed completely or partially on one or both surfaces of the ground plate. The ground plate with the disposed magnetic material can be embedded inside of or attached to at least one part (e.g., the cover) of the electronic device, the part is comprising or adjacent to the antenna. Furthermore, the antenna can comprise one or more antenna elements embedded inside of at least one part of the apparatus with each of the antenna elements electrically coupled to the ground plate. Moreover, the electronic module (e.g., printed circuit board/printed wiring board, PCB/PWB) can

comprise one or more parts and/or be embedded inside of the at least one part as well. In addition to covering the ground plane (or plate), the magnetic material can cover at least one of the following elements: an antenna, a feed pin coupling (e.g., connecting) the antenna to the electronic module, and a grounding pin coupling (e.g., connecting) the antenna to the ground plate.

It is noted that besides planar antennas such as PIFA/PILA systems, other planar and non-planar types of antennas, including but not limited to monopoles, dipoles, antenna arrays, loops, IFAs, patch antennas, etc., can be used with the magnetic materials in the ground plane according to embodiments of the present invention.

Figures 1-4 provide examples for implementing various embodiments of the present invention.

Figure 1 shows an example among others of a cross section of an antenna **20** (which can comprise one or more components) embedded inside of a part **12** of an electronic device **10** with a ground (e.g., metallic) plate **14** totally covered by a magnetic material **16** and **16a**, according to an embodiment of the present invention. The part **12** can be (but is not limited to): a cover of the device, a front cover, a back cover, a side cover, a secondary back/front cover, a combination of covers, etc. The antenna **20** is electrically coupled (connected) to the ground plate **14** with a grounding pin **22** and to electronic modules **18** and **18a** (in general, it could be multiple electronic modules) with a feed pin **26**. The electronic modules **18** and **18a** are grounded with a pin **24** to the ground plate **14**. In this arrangement the ground of the electronics can be much smaller and the antenna **20** can utilize the maximum size ground of the product space/mechanics.

Figure 2 is an example among others of a cross section of the embedded antenna **20** inside of the part **12** of the electronic device **10** with the ground plate **14** covered by the magnetic material **16** only on one side and with an electronic module **20** also embedded inside that part **12**, according to an embodiment of the present invention, as shown in Figure 2.

Figure 3 is an example among others of a cross section of the embedded antenna **20** inside of the part **12** of the electronic device **10** with the ground plate **14** covered by the magnetic material **16** only on one side and with the electronic module

20 also embedded inside that part 12, wherein the ground plate 14 is an outmost layer of the part 12, according to an embodiment of the present invention, as shown in Figure 3.

Figure 4 shows yet another example among many others of a cross section of the embedded antenna 20 inside of the electronic device 10 demonstrating a concept, wherein one or more ground plates 14a (e.g., a multipart ground) covered with magnetic material 16 are embedded in multiple parts, e.g., parts 12 and 12a of the electronic device 10, according to an embodiment of the present invention. The same concept, according to an embodiment of the present invention, can be applied to multiple electronic modules (e.g., Figure 1 shows two electronic modules 18 and 18a) which can be embedded in one or more parts of the electronic device 10.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the scope of the present invention, and the appended claims are intended to cover such modifications and arrangements.

What is claimed is:

1. An apparatus, comprising:

an antenna;

at least one electronic module electrically coupled to said antenna, for operating said antenna; and

a ground plate, electrically coupled to said antenna and to said at least one electronic module, wherein a magnetic material is disposed on said ground plate.

2. The apparatus of claim 1, wherein said magnetic material is disposed on one surface of said ground plate.

3. The apparatus of claim 1, wherein said magnetic material is disposed on both surfaces of said ground plate.

4. The apparatus of claim 1, wherein at least one surface of said ground is completely covered by said magnetic material.

5. The apparatus of claim 1, wherein at least one surface of said ground is partially covered by said magnetic material.

6. The apparatus of claim 1, wherein said ground plate with said disposed magnetic material is embedded inside of or attached to at least one part of said apparatus comprising or adjacent to the antenna.

7. The apparatus of claim 6, wherein said at least one part is a cover of said apparatus.

8. The apparatus of claim 1, wherein said antenna comprises one or more antenna elements embedded inside of at least one part of said apparatus, said one or more antenna elements being electrically coupled to the ground plate.

9. The apparatus of claim 1, wherein said at least one electronic module is embedded inside of at least one part of said apparatus.

10. The apparatus of claim 1, wherein said at least one electronic module comprises two or more electronic modules embedded in one or more parts of said apparatus.

11. The apparatus of claim 1, wherein said ground plate with said disposed magnetic material is embedded inside of or attached to two or more parts of said apparatus.

12. The apparatus of claim 1, wherein said antenna is at least one of:

a) a planar antenna,

b) a planar inverted F-antenna, and

c) a planar inverted L-antenna.

13. The apparatus of claim 1, wherein said antenna is a non-planar antenna.

14. The apparatus of claim 1, wherein said ground plate is metallic.

15. The apparatus of claim 1, wherein said magnetic material is a layer of a ferromagnetic material.

16. The apparatus of claim 1, wherein said magnetic material covers at least one of:

a) said antenna, and

b) a feed pin coupling the antenna to said at least one electronic module, and

c) a grounding pin coupling said antenna to the ground plate.

17. A method, comprising:

disposing a magnetic material on a ground plate electrically coupled to an antenna; and

electrically coupling at least one electronic module with said antenna and with said ground plate for operating said antenna.

18. The method of claim 17, wherein said magnetic material is disposed completely or partially on one surface or on both surfaces of said ground plate.

19. The method of claim 17, further comprising:

embedding said ground plate with said disposed magnetic material inside of or attached to at least one part of said apparatus comprising or adjacent to the antenna.

20. The method of claim 17, wherein said at least one electronic module is embedded inside of said at least one part.

21. The method of claim 17, further comprising:

embedding the ground plate with said disposed magnetic material inside of or attached to two or more parts of said apparatus.

22. The method of claim 17, wherein said magnetic material is a layer of a ferromagnetic material.

23. An apparatus, comprising:

means for receiving and transmitting an electromagnetic signal; and

means comprising a magnetic material for providing a ground which is electrically coupled to said means for receiving and transmitting the electromagnetic signal and to at least one electronic module for operating said means for receiving and transmitting the electromagnetic signal.

24. The apparatus of claim 23, wherein said means for receiving and transmitting an electromagnetic signal is an antenna.

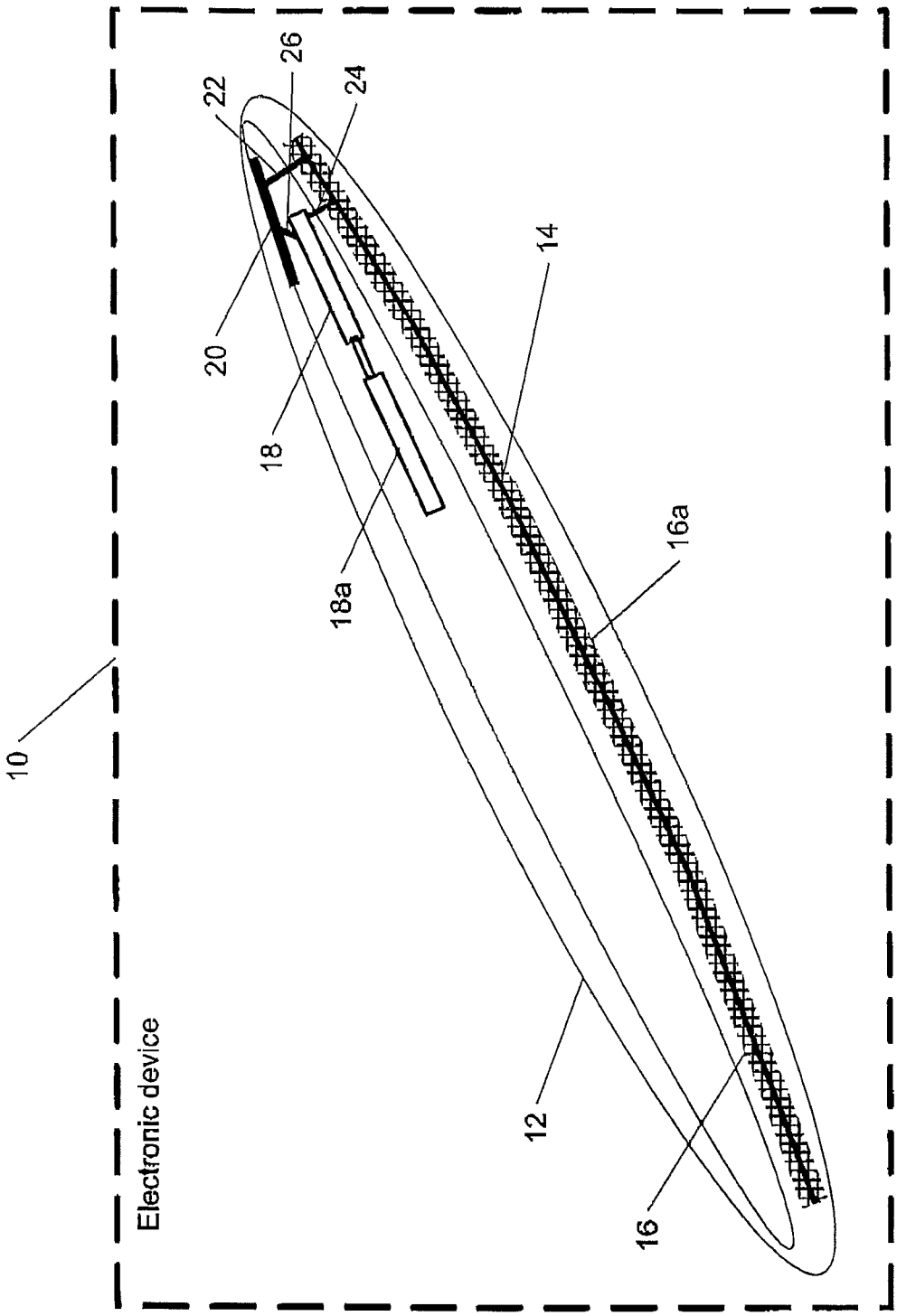


Figure 1

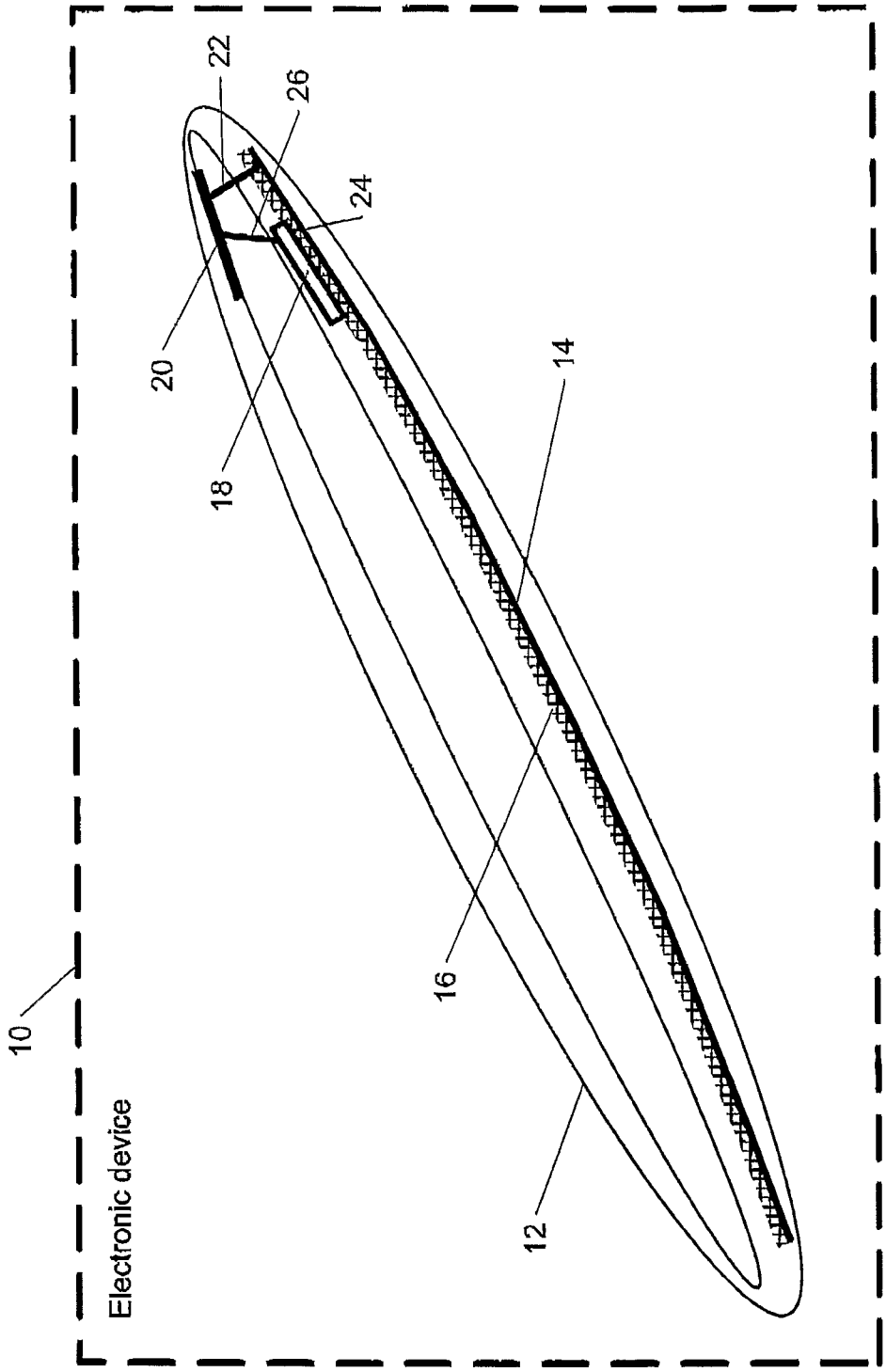


Figure 2

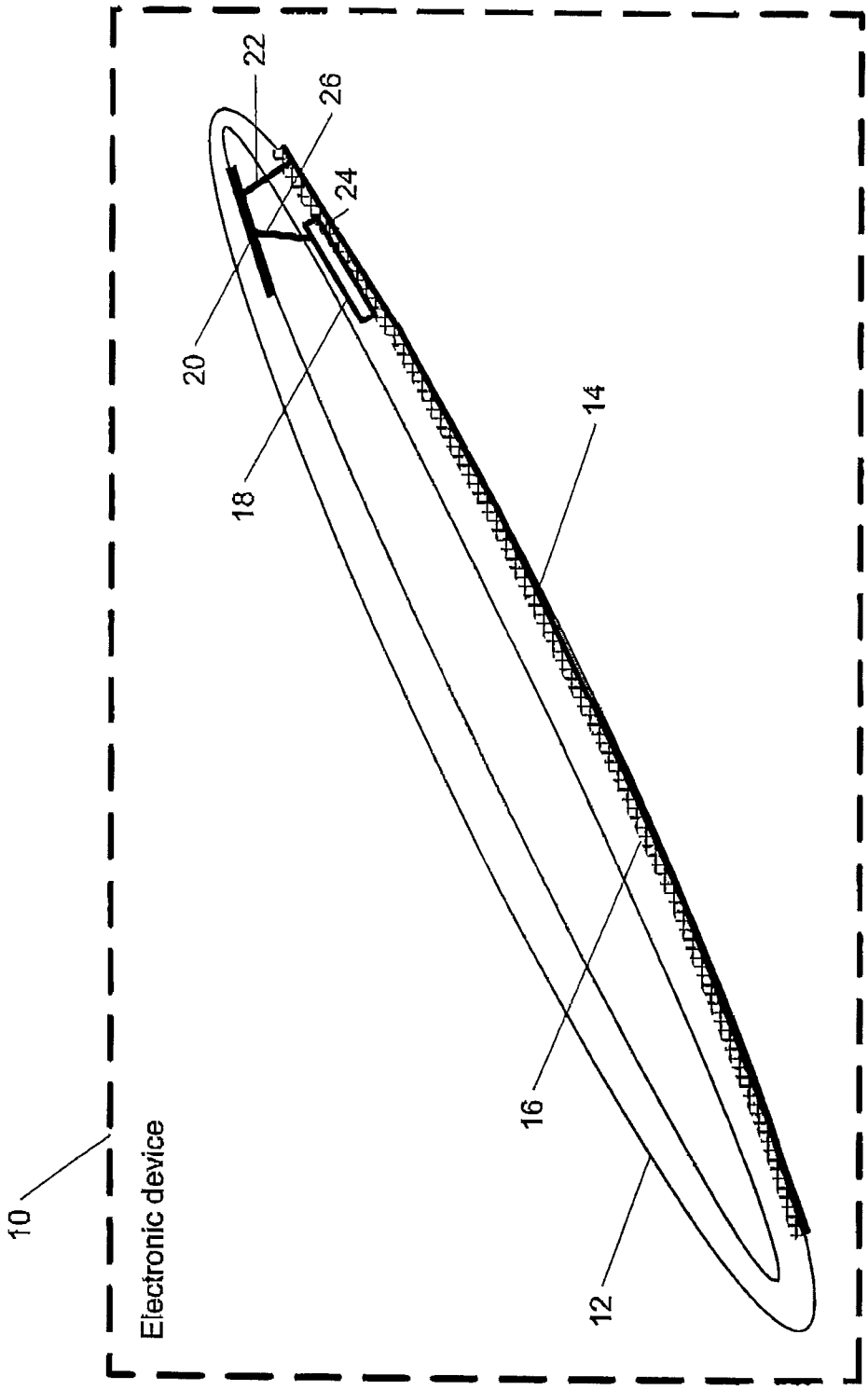


Figure 3

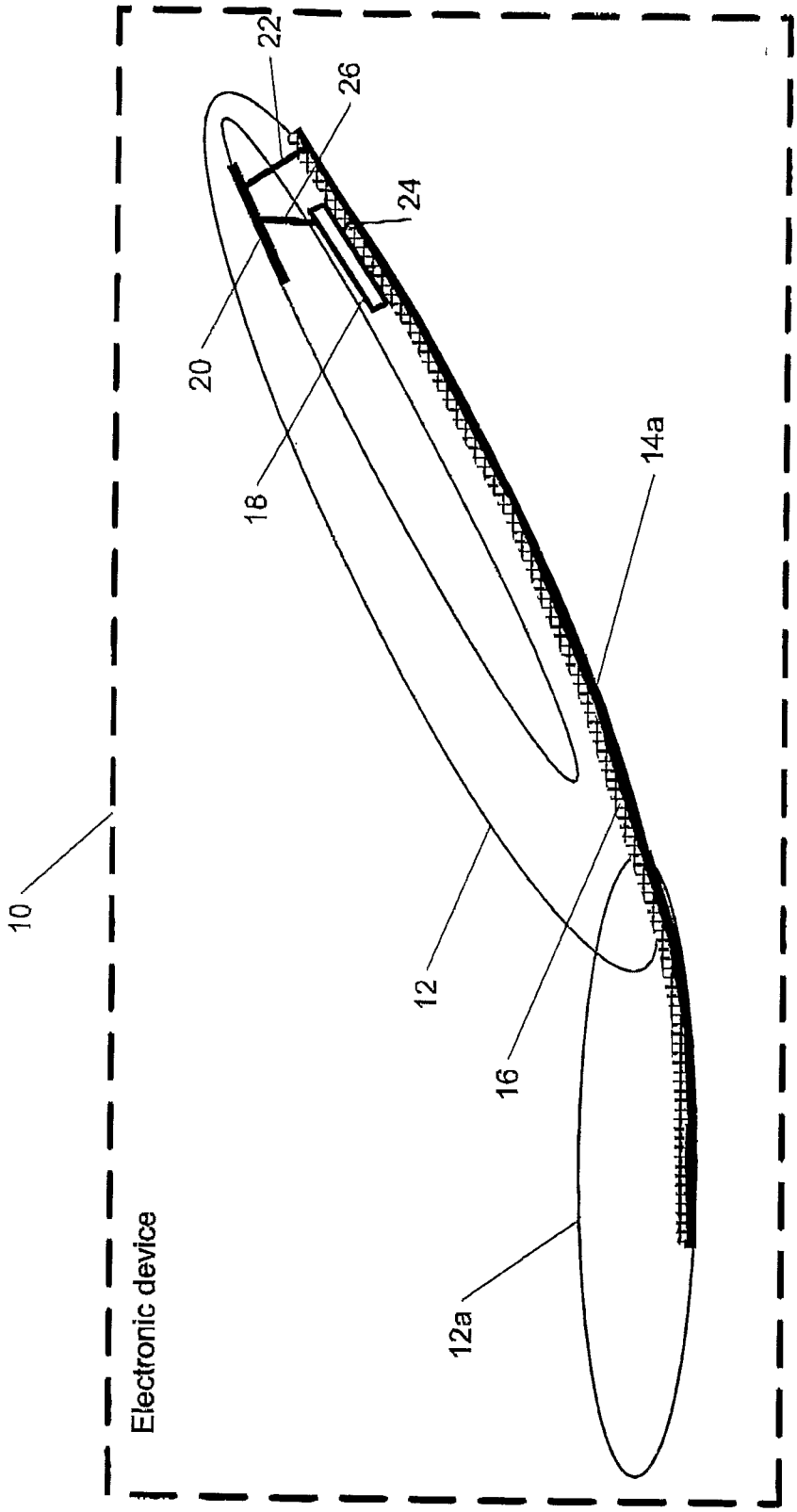


Figure 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2006/001701

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 20040104847 A1 (WILLIAM D. KILLEN ET AL.), 3 June 2004 (03.06.2004), abstract ---	1-24
A	US 20060049990 A1 (K.WATADA ET AL), 9 March 2006 (09.03.2006), abstract ---	1-24
A	US 20040189528 A1 (W.KILLEN ET AL), 30 Sept 2004 (30.09.2004), abstract ---	1-24
A	US 20040164907 A1 (W.KILLEN ET AL), 26 August 2004 (26.08.2004), abstract --- --------	1-24

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Date of the actual completion of the international search	Date of mailing of the international search report
18 January 2007	
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Cited literature, if any, will be enclosed in paper form.

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