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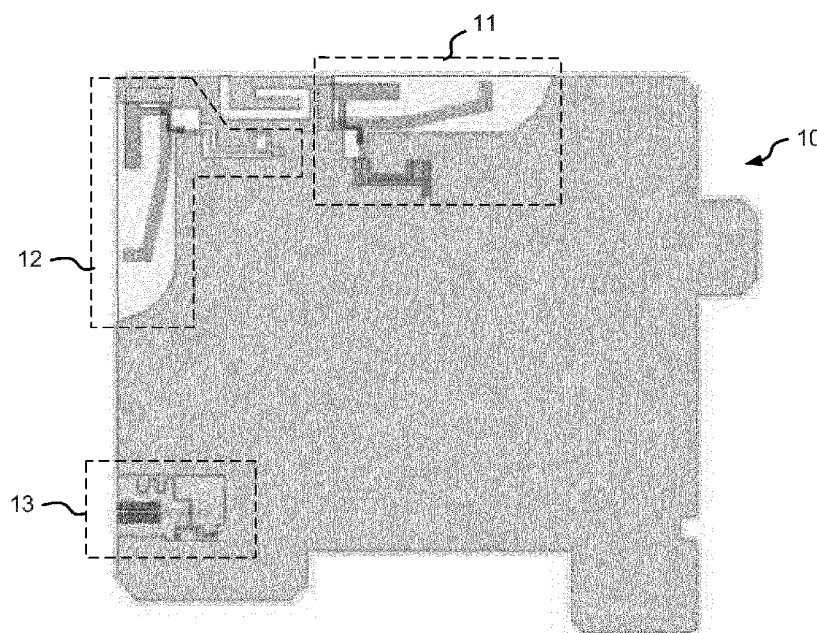


FIG. 1

(57) **Abstract:** Embodiments of the present disclosure concern an antenna device comprising a printed circuit board and at least first and second antennas printed on the printed circuit board. The printed circuit board includes at least one conductive layer. The first and second antennas are arranged to operate on a time-sharing transmission model, and the second antenna has a slot (30,31,32) etched in the conductive layer. The slot has an open end at an edge of the conductive layer. According to an embodiment of the disclosure, the antenna device further includes a shunt circuit for shunting the open end of the slot of the second antenna when the first antenna is in operation.



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ANTENNA DEVICE FOR THE COEXISTENCE OF WIRELESS SYSTEMS

1. Technical Field

The present disclosure relates generally to the field of antennas for wireless systems. Particularly but not exclusively, embodiments of the invention relate to antenna devices comprising at least two antennas provided on a printed circuit board and arranged to operate on a time-sharing transmission model, one of the antennas being a slot-type antenna.

2. Background Art

Many multimedia devices now comprise one or more antennas for exchanging data signals with other multimedia devices. These devices may comprise one or more antennas for transmitting and/or receiving data signals according to different communication standards. The multimedia device may for example comprise one or more antenna(s) for Wi-Fi communication and an antenna for Bluetooth (also referred to as BT) communication.

Embodiments of the present disclosure will be introduced for a system comprising two MIMO antennas for Wi-Fi transmissions and one antenna for BT transmissions but it will be appreciated that the invention is not limited to such a system.

Bluetooth (BT) and Wi-Fi complying with the standard IEEE-802.11 b/g/n operate in the same frequency band, between 2.4 and 2.5GHz, leading consequently to coexistence issues. Fig.1 represents a basic architecture of a printed circuit board (or PCB) used for implementing such a system. The PCB comprises two antennas, 11 and 12, for Wi-Fi communication and one antenna 13 for BT communication. These antennas are connected to respective radio chains.

Since Wi-Fi and BT operate in the same frequency band, between 2.4 and 2.5GHz, interference issues arise when they operate simultaneously. There are two ways to manage these interference issues:

1) the first way, which is the most common one, is to ensure high insulation between the Wi-Fi and the Bluetooth antennas. To achieve this there are two solutions:

1.a) physically separating the antennas, for instance by a distance of more than half wavelength; this distance may be greater than 6 cm for a 2.4GHz wireless systems; this solution enables both radios to run “freely” without each performance being degraded by the concurrent radio; it allows also each Wi-Fi and BT antenna radiating omni-directionally

without having to share the spatial radiating coverage; however this solution supposes that there is enough room to dispose the antennas in the device, which is rarely the case;

1.b) adding an isolation slot between the Wi-Fi and BT antennas or using other decoupling solutions; with this solution, the distance between antennas can be greatly reduced (lower than a quarter-wavelength) while achieving the required isolation; however the main drawback is that each antenna radiates selectively in a given direction without overlapping, thus not enabling them to radiate omni-directionally; consequently, this solution affects both Wi-Fi and BT radio performances in terms of spatial coverage; in addition, this solution still needs to have enough room to insert the isolation slot;

2/ the second way involves using an algorithm to manage the coexistence of both radios, enabling only one radio to run at the same time, sharing thus timely the wireless communication; as can be understood, with this way to manage the coexistence of the two systems, the Wi-Fi performances will depend strongly on the use case of the BT radio or inversely; if Wi-Fi is used for a video streaming application and BT is used for a remote control application, the impact for Wi-Fi will be huge and low for BT.

Embodiments of the present disclosure concern devices wherein the second way is applied. Dedicated algorithms are used to control the radios according to a time-sharing transmission model.

More specifically, embodiments of the present disclosure concerns antenna devices comprising at least two antennas operating in a same frequency band or close frequency bands, one of the two antennas being a slot-type antenna.

As will be described later in the present application in reference to Figs.1 to 7, the presence of the slot of the slot-type antenna has a negative impact on the efficiency of the other antennas of the device when they are in operation. The efficiency of the other antennas is reduced by a few percent (10% in the case of the antenna device of Figs.1 to 5).

3. Summary of Invention

Embodiments of the present disclosure set out to alleviate at least partially this drawback.

A first aspect of the disclosure relates to an antenna device comprising a printed circuit board and at least first and second antennas printed on said printed circuit board, the printed circuit board comprising at least one conductive layer, wherein said first and second antennas

are arranged to operate on a time sharing transmission model, and wherein the second antenna comprises a slot etched in said conductive layer, said slot having an open end at an edge of said conductive layer. According to an embodiment of the disclosure, the antenna device comprises a shunt circuit for shunting the open end of the slot of the second antenna when the first antenna
5 is in operation.

Indeed, simulations have demonstrated that the slot-type antenna disrupt the flow of ground currents in the conductive layer of the printed circuit board when the first antenna is in operation. In an embodiment of the disclosure, the open end of the slot is shunted when the first antenna is in operation in order to reduce the impact of the slot on the ground currents in
10 the conductive layer of PCB when the first antenna is in operation. Consequently, the efficiency of the first antenna is improved.

In a particular embodiment, the shunt circuit comprises a PIN diode.

In a particular embodiment, the PIN diode is biased when the first antenna is in operation.

15 In a particular embodiment, the antenna device comprises a bias circuit for biasing the PIN diode, said bias circuit being synchronized on the operation of the first antenna.

In a particular embodiment, the first and second antennas operate in a same frequency band, for example the frequency band [2.4-2.5 GHz].

A second aspect of the invention concerns an electronic device comprising at least one
20 antenna device comprising a printed circuit board and at least first and second antennas provided on said printed circuit board, the printed circuit board comprising at least one conductive layer, wherein said first and second antennas are arranged to operate on a time sharing transmission model, and wherein the second antenna comprises a slot provided in said conductive layer, said slot having an open end at an edge of said conductive layer.

25 The electronic device may be a device having wireless operation such as a gateway device or a set-top box.

4. Brief description of the drawings

The disclosure can be better understood with reference to the following description and
30 drawings, given by way of example and not limiting the scope of protection, and in which:

- Fig. 1 is a schematic view of an antenna device comprising two Wi-Fi antennas and one Bluetooth antenna designed on a printed circuit board, the Bluetooth being a slot-type antenna;
- 5 - Fig. 2 is an enlarged schematic view of one Wi-Fi antenna of the antenna device of Fig. 1;
- Fig. 3 is an enlarged schematic view of the Bluetooth antenna of the antenna device of Fig. 1;
- Fig. 4 is a schematic view showing the slot of the Wi-Fi antenna through the different conductive layers of the printed circuit board;
- 10 - Fig. 5 is a perspective view of the Bluetooth antenna of Fig. 3;
- Fig. 6 is a graph illustrating the isolation between the Wi-Fi antenna 12 and the Bluetooth antenna 13 of antenna device of Fig. 1;
- Fig. 7 is a graph illustrating the efficiency of the Wi-Fi antenna 12 of Fig. 1 with and without the presence of the Bluetooth antenna 13;
- 15 - Fig. 8 is a schematic view of a shunting circuit in accordance with an embodiment of the disclosure;
- Fig. 9 is a view identical to the view of Fig. 5 wherein a short circuit is placed at the open end of the slot of the Bluetooth antenna 13; and
- Fig. 10 is a graph illustrating the efficiency of the Wi-Fi antenna 12 of Fig. 1 when the
20 BT antenna 13 is equipped with a short circuit as illustrated by Fig. 9.

The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the disclosure.

5. **Description of embodiments**

- 25 Embodiments of the disclosure will be described by comparing the simulation results of the antenna system of Fig. 1 (prior art) with the simulation results of a same antenna system equipped with a shunt circuit for shunting the open end of the slot-type antenna (embodiment of the invention).

Figs. 1 to 7 refer to an antenna system not equipped with a shunt circuit as proposed by embodiments of the present invention while Figs. 8 to 10 refer to a same system antenna equipped with a shunt circuit as proposed by an embodiment of the present disclosure.

Referring to Fig. 1 and as described previously, the antenna system comprises a printed circuit board 10 and three antennas 11 to 13 printed on the printed circuit board. The printed circuit board 10 comprises a multi-layered substrate comprising three conductive layers separated from each other by dielectric layers.

In this embodiment, the antennas 11 and 12 are two identical dual-band MIMO antennas for Wi-Fi communications. These antennas are described in detail in the patent application EP2790268A1. In summary, each of these antennas comprises two cascaded PIFAs (Printed Inverted-F Antenna) each resonating in a specific portion of the Wi-Fi bands.

Fig. 2 shows a schematic view of the antenna 11. In reference to this figure, the dual-band antenna 11 comprises a first PIFA 21 on a first conductive layer and a second PIFA 22 on a second conductive layer. The ground planes are on both conductive layers. The PIFAs are cascaded in order to achieve a compact antenna. The first PIFA 21 comprises a first radiating element 210, a first feed element 211 connected to the first radiating element and a first ground return element 212 and the second PIFA 22 comprises a second radiating element 220, a second feed element 221 connected to the second radiating element and a second ground return element 222. Both ground return elements 212 222 are connected to the ground planes of all layers. Impedance matching components 23 are also provided at the common feeding port of the antenna. The operation and the detailed structure of such an antenna are described in detail in the patent application EP2790268A1 as mentioned before. Of course, other Wi-Fi antenna structures could be used for presenting embodiments of the invention.

The antenna 13, which is the BT antenna, is a compact slot antenna which described in detail in the patent application EP2725658A1. This antenna is briefly described hereinafter by referring to Figs. 3 to 5. In this brief description, M1, M2 and M3 designate the three superimposed conductive layers of the printed circuit board. These conductive layers are separated by dielectric layers D1 and D2. These layers are visible on Fig. 4.

The antenna 13 is formed by a slot-line 30 etched in the intermediate conductive layer M2 and excited at the feeding point F by electromagnetic coupling with a feeding line 34 realised in micro-strip technology, either on the upper face of the dielectric layer D1 or on the lower face of the dielectric layer D2. The slot-line 30 continues by a slot-line 31 realised in the upper conductive layer M1 then by a slot-line 32 realised in the lower conductive layer M3,

the slot-lines 30, 31, 32 being superimposed and their total electrical length being equal to $k \cdot \lambda_g$ where λ_g is the wavelength at the operating frequency. The feeding line 34 is connected to an impedance matching circuit 35.

As shown in Fig. 3 and/or Fig. 5, the slot-line 31 realised in the conductive layer M1 is delimited by two conductive strips S31 and S'31. Identically, the slot-line 32 is delimited by two conductive strips S32, S'32 in the conductive layer M3. To obtain a continuous radiating slot-line, the different conductive strips are interconnected in the following manner. The intermediate conductive layer M2 has, on each side of the slot-line 30, at the feeding side, two apertures W, W' through which pass two via-holes V1, V1' respectively connecting one of the ends of the conductive strip S31 to the corresponding end of the conductive strip S32 and one of the ends of the conductive strip S'31 with the corresponding end of the conductive strip S'32. The other end of the conductive strip S31 is connected through a via-hole V2 to the conductive layer M2 and to an isolated element EM of the conductive layer M3 located in the continuation of the conductive strip S32. Likewise, the end of the conductive strip S'31 is connected to the intermediate layer M2 and to an isolated element EM' of the conductive layer M3 located in the continuation of the conductive strip S'32. This enables a connection to be obtained between the different slot-lines 30, 31, 32 as shown by the arrows in FIG. 4. These antennas have been 3D electromagnetically simulated with predefined mechanical and environmental constraints. The simulation results are illustrated by graphs of Fig. 6 and Fig. 7.

Fig. 6 shows the isolation between the antenna 12 (Wi-Fi antenna) and the antenna 13 (BT antenna). As can be seen in this figure, the isolation level is around 11dB in the 2.4-2.5 GHz band. This level is low.

Fig. 7 shows two curves illustrating the efficiency of the antenna 12 in the presence and in the absence of the slot-type antenna 13. This Figure shows that, in presence of the slot-type antenna, the efficiency of the antenna 12 is reduced by around 10-12%, from around 70% to less than 60%, which is critical.

This is the problem that some embodiments of the disclosure aim to deal with.

According to an embodiment of the disclosure, it is proposed to provide the antenna device with a shunt circuit for shunting the open end of the slot of the slot-type antenna when the other antenna(s) of the antenna system is in operation in order to preserve the intrinsic performances of this or these other antenna(s). In case of the antenna system of Fig. 1, a shunt circuit 35 is provided between both sides of the open end of the slot of the antenna 13.

An example of shunt circuit 35 is shown schematically on Fig. 8. It comprises a PIN diode 350 and a bias circuit 351 for biasing the PIN diode, the whole circuit being placed between two connexion points P1 and P2 connected to both sides of the open end of the slot of the slot-type antenna. The bias circuit 351 comprises two capacitors C1 and C2 and an inductor L1 arranged to bias the diode 350 and control its state (conducting or not conducting) as a function of a control voltage Vb.

The role of the shunt circuit 35 is to neutralize the effect of the slot on the surrounding antennas of the antenna device when the latter are in operation.

The shunting of the open end of the slot of the antenna 13 has been simulated by providing the open end of the slot of the antenna 13 with a short circuit SC acting as a shunt circuit as shown in Fig. 9. In this figure, a metal strip forming the short circuit SC is placed at the open end of the slot.

Fig. 10 shows two curves illustrating the efficiency of the antenna 12 in the presence and in the absence of the slot-type antenna 13 equipped with the shunt circuit 35.

As can be seen on Fig. 10, the efficiency of the antenna 12 is recovered when the slot of the antenna 13 is shunted.

This example shows that the efficiency degradation of the antenna 12 can be at least partially avoided by equipping the slot-type antenna 13 with a shunt circuit as disclosed hereinabove.

The shunt circuit is advantageously a PIN diode and the bias circuit of the PIN diode is synchronized on the operation of the antenna 12. More specifically, the biasing of the PIN diode is synchronized with the operation of the antenna 12 such that:

- the diode provides a short circuit when the antenna 12 is in operation, and
- the diode provides an open circuit when the antenna 12 is not in operation.

In the embodiment described hereinabove, the antenna device comprises one slot-type antenna (antenna 13) and two PIFA antennas (antennas 11 and 12). Of course, the antenna device could comprise only one slot-type antenna and one PIFA antenna.

In addition, the antenna(s) 11 and/or 12 are antennas designed on a PCB and not necessarily PIFA antennas.

Likewise, in the embodiment described hereinabove, the slot-type antenna (antenna 13) and the PIFA antennas (antennas 11 and 12) operates in a same frequency band. Embodiments of the invention could be applied to antennas operating in close frequency bands.

CLAIMS

1) Antenna device comprising a printed circuit board (10) and at least first and second antennas (12,13) provided on said printed circuit board, the printed circuit board comprising at least one conductive layer, wherein

said first and second antennas (12,13) are arranged to operate on a time-sharing transmission model, and

the second antenna (13) comprises a slot (30,31,32) provided in said conductive layer, said slot having an open end at an edge of said conductive layer, and

the antenna device further comprises a shunt circuit (35) for shunting the open end of the slot of the second antenna when the first antenna (12) is in operation.

2) Antenna device according to claim 1, wherein the shunt circuit (35) comprises a PIN diode (350).

3) Antenna device according to claim 2, wherein the PIN diode (350) is biased when the first antenna (12) is in operation.

4) Antenna device according to claim 2 or 3, further comprising a bias circuit for biasing the PIN diode, said bias circuit being synchronized on the operation of the first antenna.

5) Antenna device according to any one of claims 1 to 4, wherein the first and second antennas (12,13) operate in a same frequency band.

6) Antenna device according to any preceding claim wherein the first antenna comprises a PIFA antenna.

7) An electronic device comprising an antenna device according to any preceding claim.

8) An electronic device according to claim 7 wherein the electronic device is a gateway device or a set-top box.

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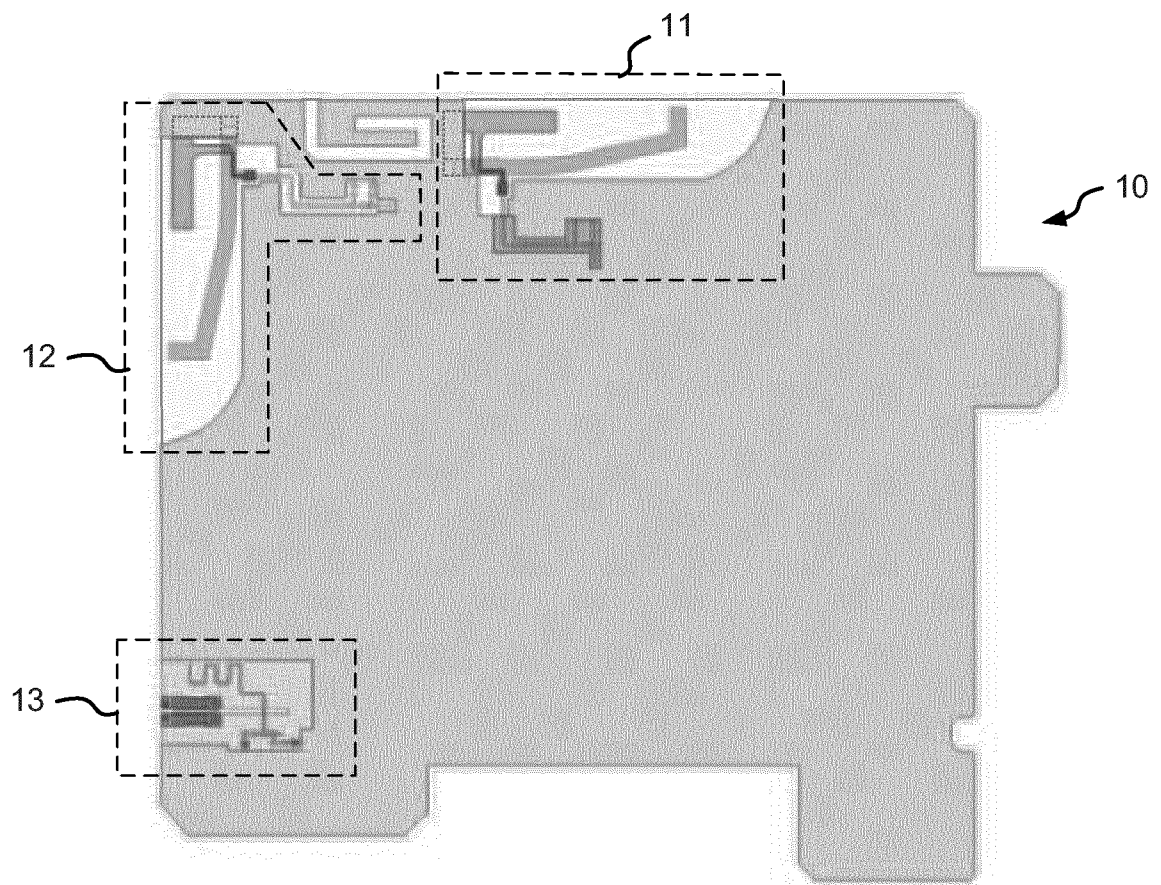


FIG.1

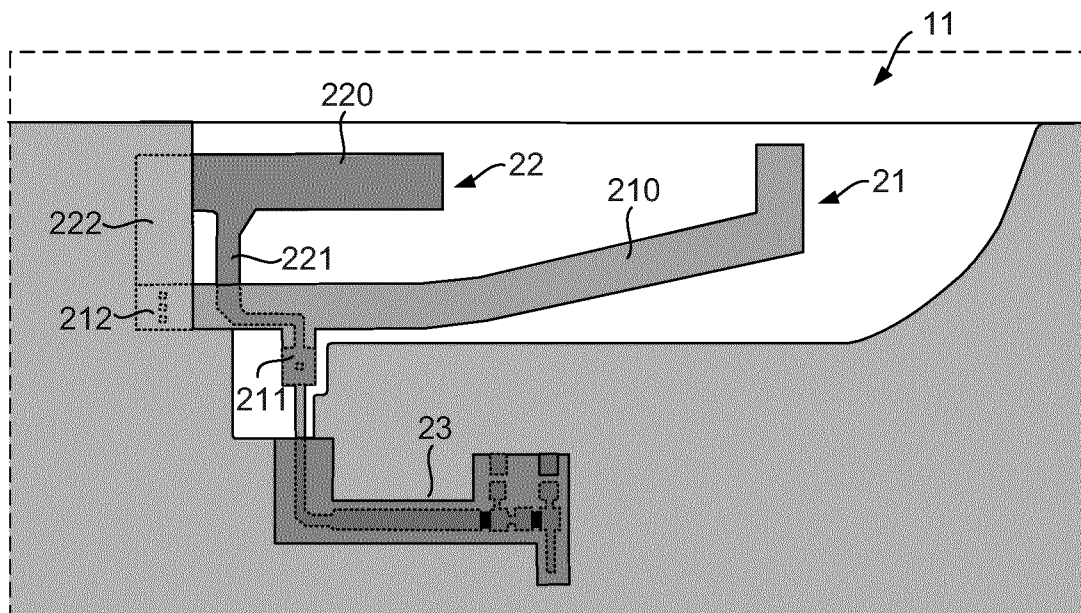


FIG.2

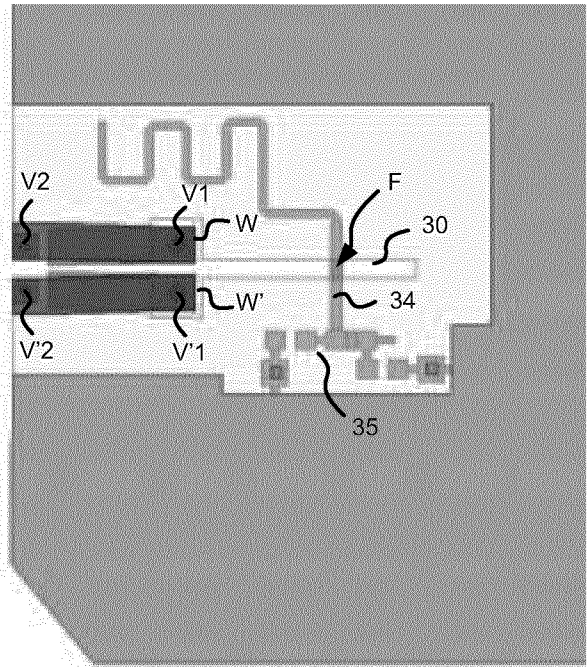


FIG.3

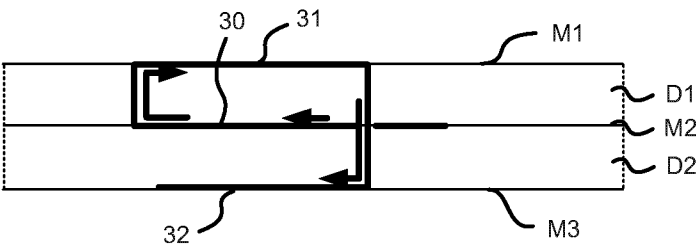


FIG.4

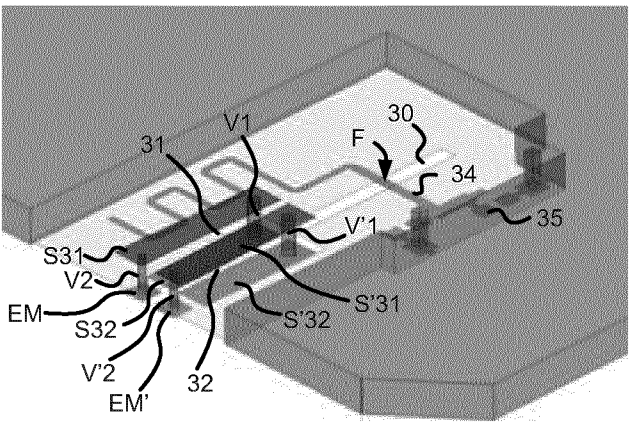
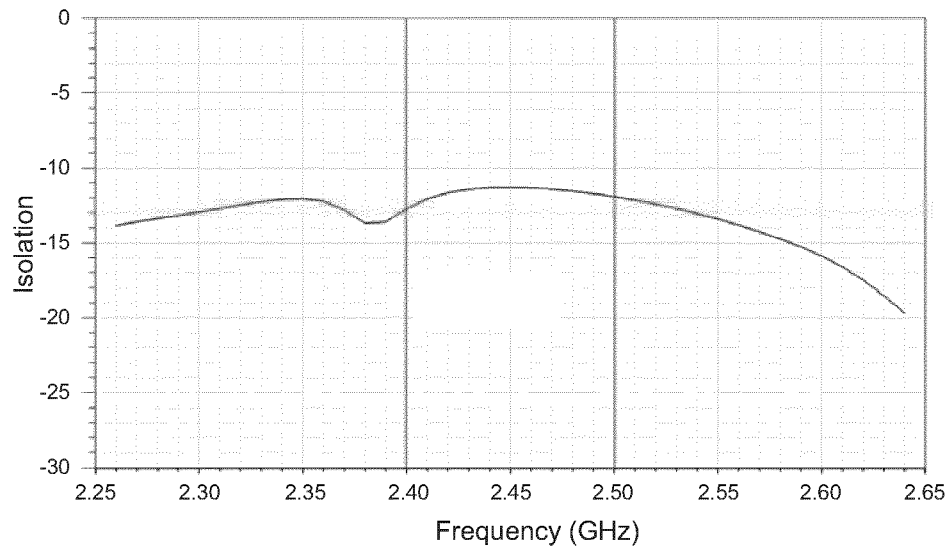
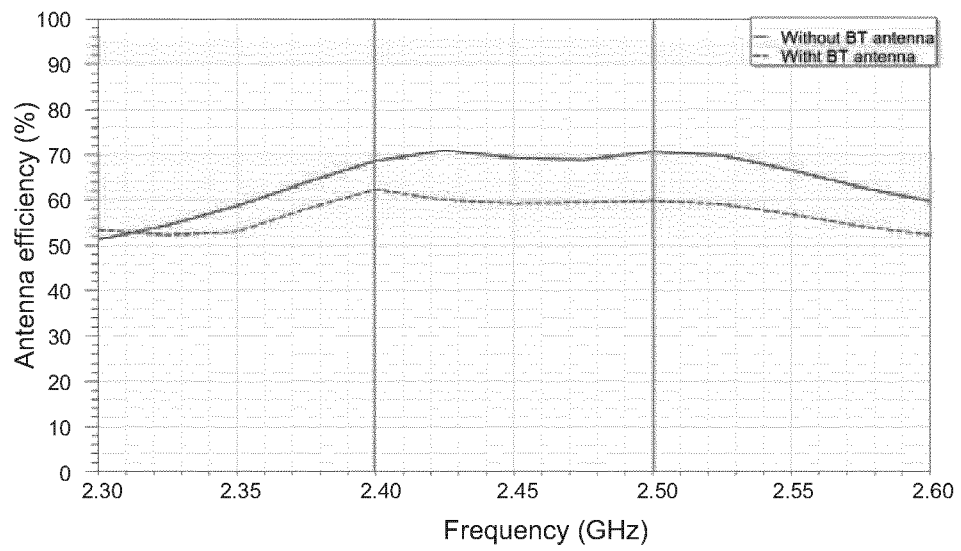


FIG.5

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**FIG.6****FIG.7**

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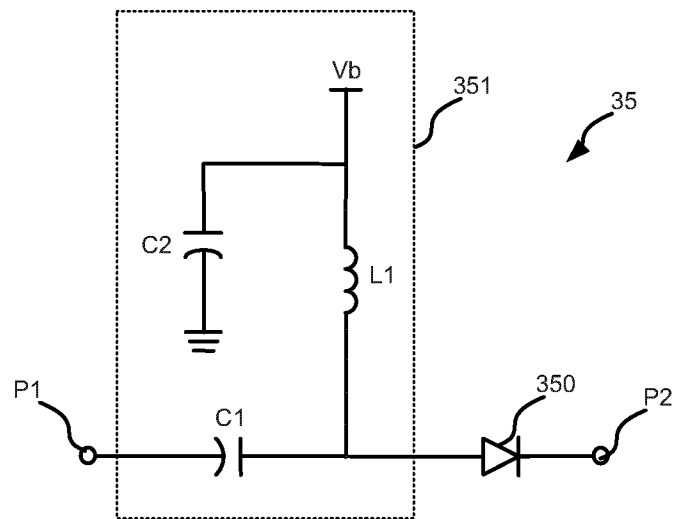


FIG.8

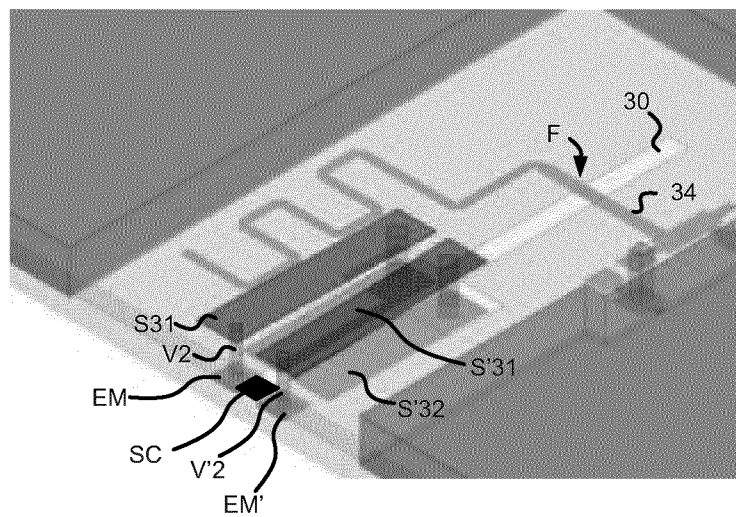


FIG.9

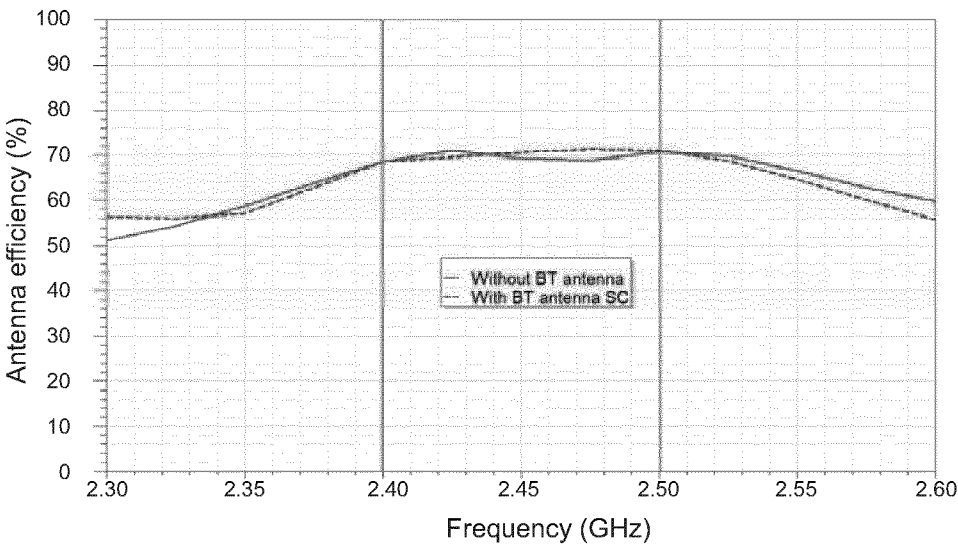


FIG.10

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/060122

A. CLASSIFICATION OF SUBJECT MATTER INV. H01Q1/38 H01Q1/52 H01Q13/10 H01Q21/28 H01Q1/48 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) H01Q		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/043201 A1 (PELOSI MAURO [DK] ET AL) 13 February 2014 (2014-02-13) abstract; figures 2, 5 paragraphs [0002], [0007], [0026] - [0069] -----	1-8
A	EP 0 548 975 A1 (TOSHIBA KK [JP]) 30 June 1993 (1993-06-30) abstract; figure 44 column 17, line 45 - column 19, line 35 -----	1-8
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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Date of the actual completion of the international search 26 July 2017		Date of mailing of the international search report 02/08/2017
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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