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(54) Title: MOBILE COMMUNICATION DEVICE WITH IMPROVED ANTENNA PERFORMANCE

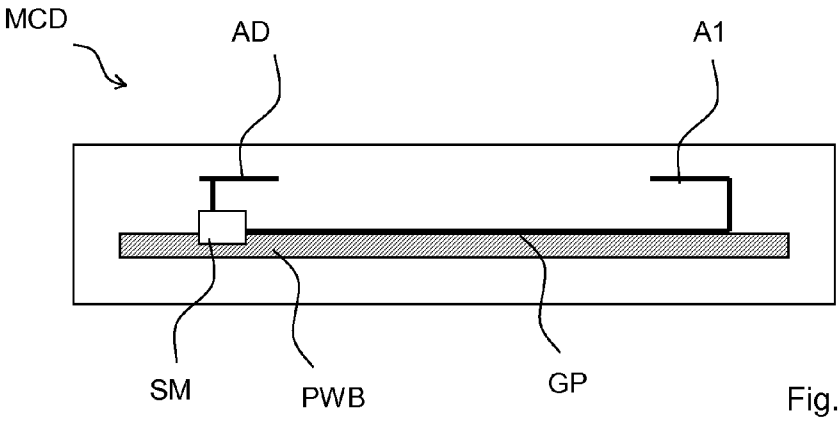

Fig. 1

(57) Abstract: Mobile communication devices with improved antenna performance are provided. A mobile communication device comprises a first antenna, a ground plane, and a diversity antenna. In a mode of operation which is not a multi-antenna transmission mode, the diversity antenna is electrically coupled to the ground plane. The diversity antenna increases the electrical length of the ground plane and enhances the antenna performance of the radiating assembly of the first antenna in combination with the ground antenna and the diversity antenna.

Description

Mobile communication device with improved antenna performance

The present invention relates to mobile communication devices offering improved antenna performance.

Modern mobile communication devices need to be small and lightweight but have to support multiple frequency bands or multiple communication standards, such as GSM (Global System for Mobile Communications), (W)CDMA ((Wideband) Code Division Multiple Access), or LTE (Long-Term Evolution). LTE, a communication standard of the fourth generation, 4G, enables operating two antennas simultaneously. Multi-antenna transmission modes in LTE systems can improve the service capabilities of a communication device. Therefore, a mobile communication device can comprise a main antenna and a diversity antenna.

From US 7,505,006 B2, an antenna arrangement comprising a coupling antenna element and an extension element is known. An antenna element has a first resonant frequency and a first bandwidth and the extended conductive element has a second resonant frequency and a second bandwidth. Thus, an antenna arrangement is provided that can cover a broad range of frequencies.

From US 2010/0081407 A1 filter stages for high data rates are known. In one embodiment of a "diversity receiver" a switch has a switching state in which an antenna is electrically connected to an impedance which is chosen so that a phase angle caused by the reflection allows for optimizing mutual coupling between the antenna and a further antenna.

However, current demands towards smaller communication devices inhibit designers of modern communication devices to include additional antenna components within modern communication devices although communication devices with improved antenna performance are needed. An improved antenna performance e.g. helps saving energy.

It is an object of the present invention to provide a mobile communication device that supports multiple frequency bands and multiple communication standards, that allows to be integrated into a smaller housing, and that has a better antenna performance.

The present invention provides a mobile communication device comprising a ground plane, a first antenna and a diversity antenna. The first antenna can couple electromagnetically to the ground plane during operation. A diversity antenna can couple electromagnetically to the ground plane during operation, too. During operation of the first antenna, the coupling of the diversity antenna to the ground plane enhances the performance of the first antenna, especially when said diversity antenna coupling is optimized by using suitable load between diversity antenna and the ground plane.

The coupling of the diversity antenna to ground plane may be different when it is used for diversity reception and when used to enhance the performance of the first antenna. Therefore, different coupling circuits having different impedances or the same coupling circuit having an adjustable impedance can be utilized.

Such a mobile communication device has an antenna with improved antenna performance. As the mobile communication

device comprises a first antenna, which may be a main antenna, and a diversity antenna, it is well suited for multi-antenna transmission modes of, for example, LTE systems.

Usually, a main antenna and its ground plane couple electromagnetically and work as a radiating element. The inventors found that increasing the electrical length of a ground plane of a mobile communication yields an increased frequency bandwidth of this radiating element. Thus, a longer ground plane yields a broader bandwidth. An enhanced bandwidth yields better matching and better radiating efficiency at the edges of the frequency bands. However, the trend towards smaller communication devices forbids increasing the lateral dimensions of the ground plane.

Further, the inventors found that the electrical length of a ground plane can be increased by electromagnetically coupling the ground plane to an additional radiating element. However, adding additional radiating elements to a mobile communication device is - again - detrimental in view of the trend towards smaller devices.

Electromagnetically coupling the ground plane to a diversity antenna that is needed by a communication device for multi-antenna transmission modes anyway and is, hence, already present in the device, however, yields a better antenna performance of the main antenna without the need to add further radiating elements to the communication device.

Thus, the first antenna of the present invention may be a main antenna of a mobile communication device.

Further, to get maximum benefit from the diversity antenna, the diversity antenna should be located as far as possible from the main antenna. It is, therefore, possible to locate the diversity antenna and the first antenna at opposite ends or sides of an according mobile communication device to get an optimal performance.

In an according mobile communication device, the first antenna, the ground plane and the diversity antenna work together and act as a radiating element that has a better performance compared to an antenna assembly comprising only the first antenna and the ground plane.

In practice, the diversity antenna becomes a radiating part of the ground plane increasing the electrical length of the ground plane.

Coupling a diversity antenna electromagnetically to a ground plane, e.g. during a communication standard that does not need multi-antenna transmission modes, is not a triviality: one aspect in gaining a lightweight mobile communication device is reducing the weight of the device's battery. Then, however, the power consumption of the mobile communication device has to be reduced to allow sufficient time of operation. The most important step in reducing the power consumption of the mobile communication device is to deactivate every component that is not needed during a current operation mode. In multi-antenna transmission modes, the diversity antenna cannot be deactivated. For example, in GSM communication mode the diversity antenna is not used for communication and is usually switched off together with all diversity reception related electronics. In WCDMA, the usage of diversity antenna is optional, here also it could be

switched off or used for other purposes. It is clear that the diversity antenna and its related electronics would be deactivated in WCDMA mode when saving energy is important.

However, the inventors found that energy can also be saved if the antenna performance is enhanced. This is because less power has to be transmitted via an antenna with a reduced insertion loss.

Thus, it is possible to reduce the power consumption of a mobile communication device by keeping a diversity antenna active although it is not used for multi-antenna transmission modes.

As the first antenna, the ground plane and the diversity antenna act as a radiating element, it is clear that the ground plane cannot be regarded as being on a strict ground potential. The ground plane may be electrically connected to a ground connection but the electromagnetic potential of the ground plane may not be the electromagnetic potential of a conventional ground.

In one embodiment, coupling the diversity antenna to the ground plane enhances the bandwidth of the first antenna by a factor of at least 1,1 or 1,3 or more. Therefore, a predefined load impedance of a coupling circuit can be utilized.

Enhanced bandwidth causes a better efficiency, e.g. reduced insertion loss, at the edges of a frequency band.

In one embodiment of the present invention, coupling the diversity antenna to the ground plane enhances the

transmission coefficient of the first antenna by at least 3 dB.

A reduction by 3 dB correlates to a Tx power consumption that is reduced by 50%. Thus, although energy has to be spent to keep the diversity antenna active, energy can be saved in total.

In one embodiment, the first antenna and the diversity antenna are specified for an LTE communication device.

In one embodiment, the first antenna and the diversity antenna are arranged on opposite ends of the ground plane. Then, the benefit from the diversity antenna is enhanced as the electrical length of the ground plane is maximized.

In one embodiment, the device further comprises a PWB (PWB = Printed Wiring Board) where the ground plane is arranged on the PWB. The PWB comprises an electrically insulating material having a dielectric constant κ. The dielectric constant κ determines the capacity and the inductance of the ground plane. The dielectric constant κ is chosen to enhance the antenna's performance. However, the geometrical dimensions of the ground plane are important to obtain a good antenna characteristic, too.

In one embodiment, the ground plane has a first electrical length and the diversity antenna has a second electrical length and the combination of the first antenna and the ground plane has an electrical length. The electrical length of this combination is longer than each of the lengths of the antenna or the ground plane alone.

In one embodiment, coupling the diversity antenna to the ground plane enhances the performance of the first antenna in a GSM operation mode, in a WCDMA operation mode, or in a LTE TDD (TDD = time division Duplexing) operation mode.

A LTE TDD operation mode can also benefit from a diversity antenna coupled to the ground plane. The diversity antenna - which may be a MIMO antenna (MIMO = multiple-input and multiple-output) - could be used to improve the main antenna performance during the Tx slot and used as MIMO or diversity antenna during the Rx slot. LTE TDD is similar to GSM in that aspect that is has time divided Tx and Rx slots.

In principle, it is possible to enhance the performance of the first antenna in any operation mode that does not necessarily need the diversity antenna active.

In one embodiment, the diversity antenna is terminated with a bandpass filter or with a predefined load. The bandpass filter or the predefined load establish the coupling circuit. Again, the phrase "termination" does not mean applying the electromagnetic potential of the ground plane to a ground potential, but changing the coupling by this load. In this context, terminating the diversity antenna with a bandpass filter or with a predefined load means that a bandpass filter or a predefined load is electrically connected between the diversity antenna and the ground plane. With such a termination, the electromagnetical coupling between the ground plane and the diversity antenna is established without the need for further impedance elements.

In one embodiment, the mobile communication device further comprises a switch that provides an electrical connection

between the diversity antenna on one side and a bandpass filter or a predefined load impedance on the other side. With such a switch, the termination of the antenna can be matched individually in response to changes in environmental conditions.

The present invention will become fully understood from the detailed description given hereinbelow and the accompanying schematic drawings. In the drawings:

FIG. 1 shows a basic version of the present mobile communication device,

FIG. 2 shows a part of the equivalent circuit diagram,

FIG. 3 shows the impedance of the first antenna while the diversity antenna is in use in a multi-antenna operation mode,

FIG. 4 shows the return loss S_{11} of the first antenna while the diversity antenna is in use in a multi-antenna operation mode,

FIG. 5 shows the impedance of the first antenna while the diversity antenna is terminated via a predefined load impedance,

FIG. 6 shows the return loss S_{11} of the first antenna while the diversity antenna is terminated via a predefined load impedance,

FIG. 7 shows the impedance of the first antenna while the diversity antenna is terminated via a bandpass filter,

FIG. 8 shows the return loss S_{11} of the first antenna while the diversity antenna is terminated via a bandpass filter.

FIG. 1 shows a basic version of a mobile communication device MCD of the present invention. The mobile communication device MCD comprises a printed wiring board PWB on which a ground plane GP is arranged. The mobile communication device MCD further comprises a first antenna A1 and a diversity antenna AD. The diversity antenna AD is electrically connected to the ground plane GP via switching means SM. The switching means SM may comprise a predefined load impedance or a bandpass filter of the mobile communication device MCD.

FIG. 2 shows parts of an equivalent circuit diagram of the present mobile communication device. The device comprises a first antenna A1 and a diversity antenna AD. The diversity antenna AD is electrically connected to a switch SW. The switch SW can establish an electrical connection between the diversity antenna AD and a bandpass filter BPF. Alternatively, the switch SW can establish an electrical connection between the diversity antenna AD and a predefined load impedance L. The load impedance L electrically connects the diversity antenna AD with the ground plane GP.

The first antenna A1 is electrically connected to a signal line SL of the mobile communication device.

FIG. 3 shows the frequency dependent impedance of the first antenna within a frequency interval from 700 MHz to 1 GH. Mark M901 denotes the frequency 901 MHz. Mark M832 denotes the frequency 832 MHz. The meaning of these frequencies will become understood in FIG. 4.

FIG. 4 shows the return loss S_{11} of the first antenna while the diversity antenna is in use in a multi-antenna transmission mode such as LTE. For simplicity's sake, a return loss of 6 dB defines the edges of the band in which the first antenna can be operated. The return loss is better than -6 dB within a frequency interval reaching from 832 MHz, denoted by marker M832, and 901 MHz, denoted by marker M901. Thus, the bandwidth equals 69 MHz. The smallest return loss is approximately -8,25 dB.

In contrast, FIG. 5 shows the frequency dependent impedance of the first antenna while the diversity antenna is not in use in a multi-antenna transmission mode but is electrically coupled to the ground plane. The diversity antenna is terminated via a predefined load impedance. Mark 907 denotes the frequency 907 MHz. Mark 817 denotes the frequency 817 MHz. These frequencies establish the -6 dB frequency gap shown in FIG. 6.

As can be seen in FIG. 6, the return loss of the first antenna is better than -6 dB in a frequency interval going from 817 MHz to 907 MHz. The width of the frequency band is 90 MHz. Thus, the width of the frequency band is enhanced by 21 MHz. Further, the minimum return loss is below -10 dB within the frequency band. It can clearly be seen that the bandwidth is enhanced and the return loss is enhanced, too, by terminating the diversity antenna via a predefined load impedance. Compared to the situation of fig. 4 that bandwidth is enhanced by (90-69)/60 = 0,30 = 30 %, i.e. by a factor of 1,3. Further, the return loss is improved by more than 3 dB.

FIG. 7 shows the frequency dependent impedance of the first antenna for a situation where the diversity antenna is

terminated via a bandpass filter. Mark 901 denotes the frequency 901 MHz; mark M821 denotes the frequency 821 MHz.

As can be seen in FIG. 8, the -6 dB frequency band goes from 822 MHz to 901 MHz. The width of the frequency band is 79 MHz. Compared to the situation shown in FIG. 4, the antenna performance of the first antenna is enhanced. The bandwidth is enhanced by (79-69)/60 = 0,14 = 14 %, i.e. by a factor of 1,14.

The present invention may comprise a termination of a diversity antenna via a predefined load impedance or via a bandpass filter. By electromagnetically coupling the diversity antenna to the ground plane of a mobile communication device, the antenna performance of the main antenna is improved. But the basic concept does not depend on details concerning this coupling. The invention is not restricted by the embodiments of the accompanying figures. Especially embodiments based on further coupling means such as inductive or capacitive elements or signal lines or strip lines are also possible. Thus, numerous variations departing from the figures are possible without departing from the invention.

List of reference signs:

A1:	first antenna
AD:	diversity antenna
BPF:	bandpass filter
GP:	ground plane
L:	predefined load impedance
M817:	mark denoting the frequency 817 MHz
M822:	mark denoting the frequency 822 MHz
M832:	mark denoting the frequency 832 MHz
M901:	mark denoting the frequency 901 MHz
M907:	mark denoting the frequency 907 MHz
MCD:	mobile communication device
PWB:	printed wiring board
SL:	signal line
SM:	switching means
SW:	switch

Claims:

1. Mobile communication device (MCD) comprising
- a ground plane (GP),
- a first antenna (A1) that can couple electromagnetically to the ground plane (GP) during operation,
- a diversity antenna (AD) that can couple electromagnetically to the ground plane (GP) during operation, where
- during operation of the first antenna (A1), the coupling of the diversity antenna (AD) to the ground plane (GP) enhances the performance of the first antenna (A1).

2. Device of the preceding claim, where coupling the diversity antenna (AD) to the ground plane (GP) enhances the bandwidth of the first antenna (A1) by a factor of at least 1,1.

3. Device of one of the preceding claims, where coupling the diversity antenna (AD) to the ground plane (GP) enhances the transmission coefficient of the first antenna (A1) by at least 3 dB.

4. Device of the preceding claim, where the first antenna (A1) and the diversity antenna (AD) are specified for a LTE communication device.

5. Device of one of the preceding claims, where the first antenna (A1) and the diversity antenna (AD) are arranged on opposite ends of the ground plane (GP).

6. Device of one of the preceding claims, further comprising a printed wiring board (PWB) where the ground plane (GP) is arranged on the printed wiring board (PWB).

7. Device of one of the preceding claims, where coupling the diversity antenna (AD) to the ground plane (GP) enhances the performance of the first antenna in a GSM operation mode, in a WCDMA operation mode, or in a LTE TDD operation mode.

8. Device of one of the preceding claims, where the diversity antenna (AD) is terminated with a band pass filter (BPF) or with a predefined load impedance (L).

9. Device of one of the preceding claims, further comprising a switch (SW) that provides an electrical connection between the diversity antenna (AD) on one side and a band pass filter (BPF) or a predefined load impedance (L) on the other side.

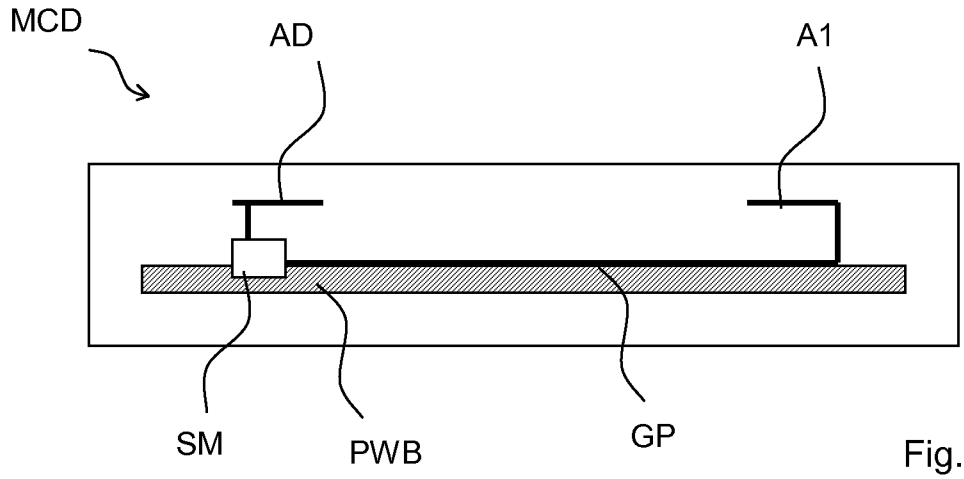

Fig. 1

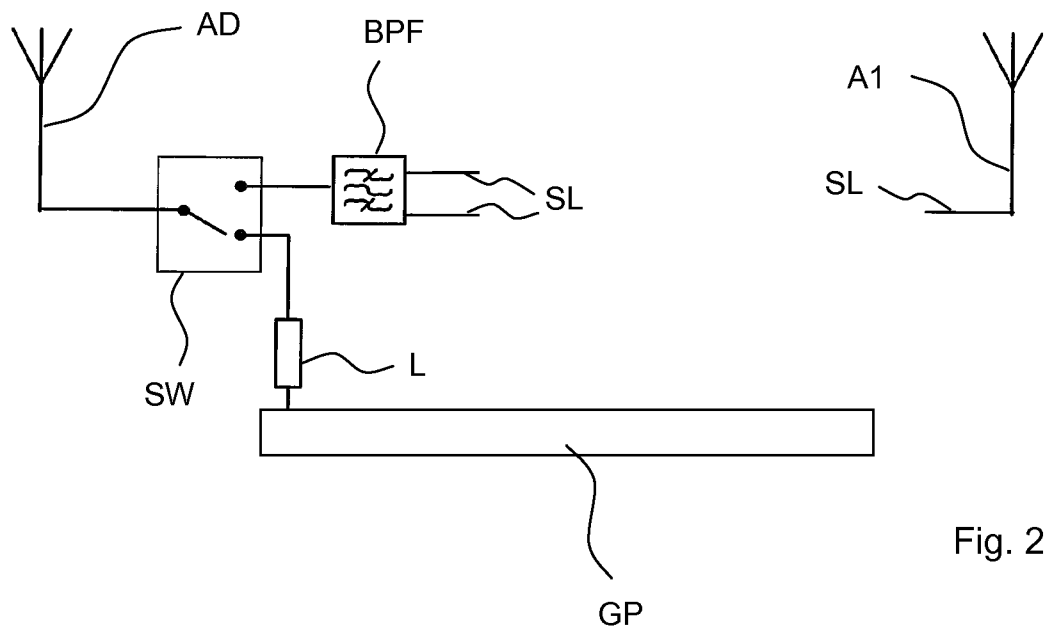

Fig. 2

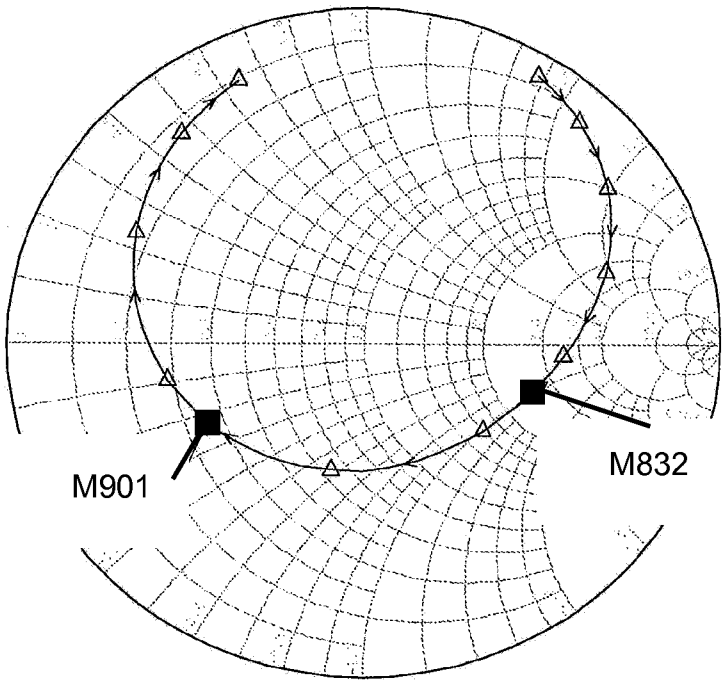

Fig. 3

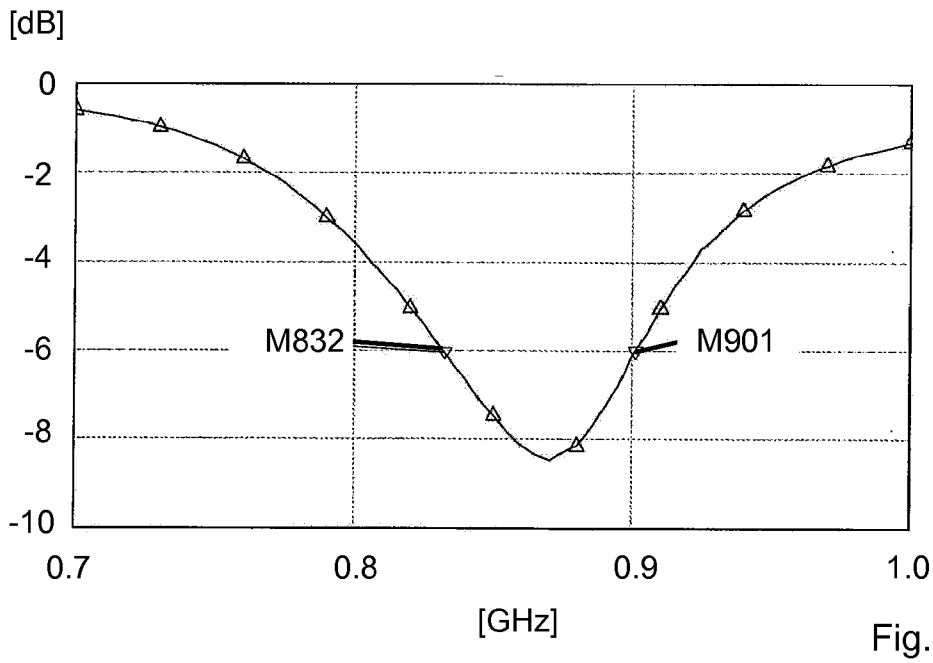

Fig. 4

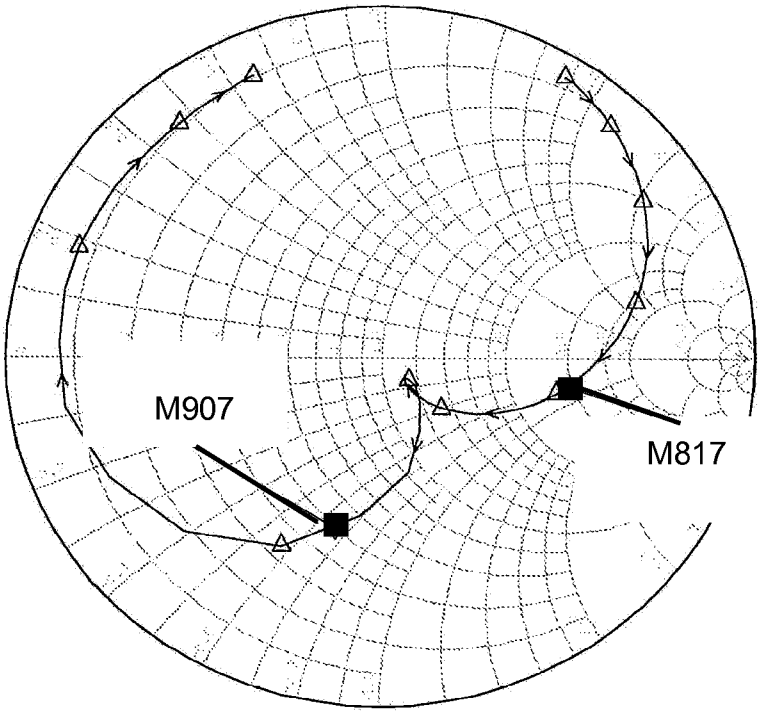

Fig. 5

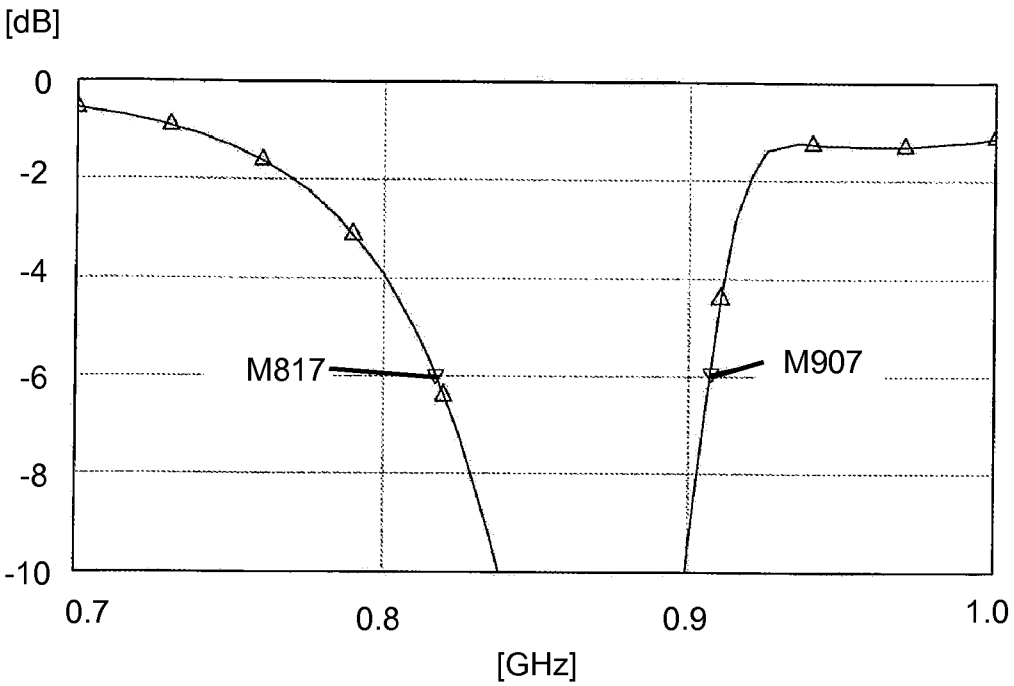

Fig. 6

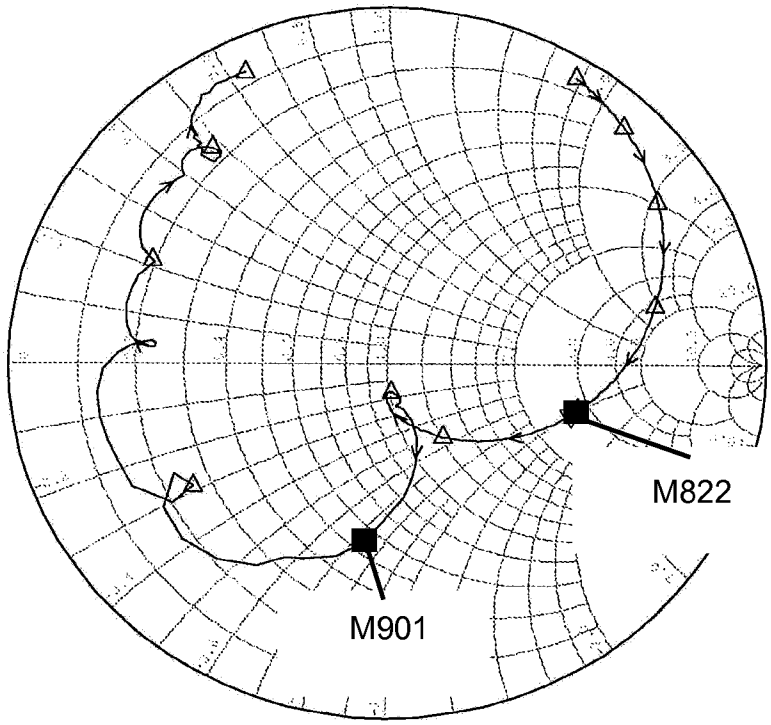

Fig. 7

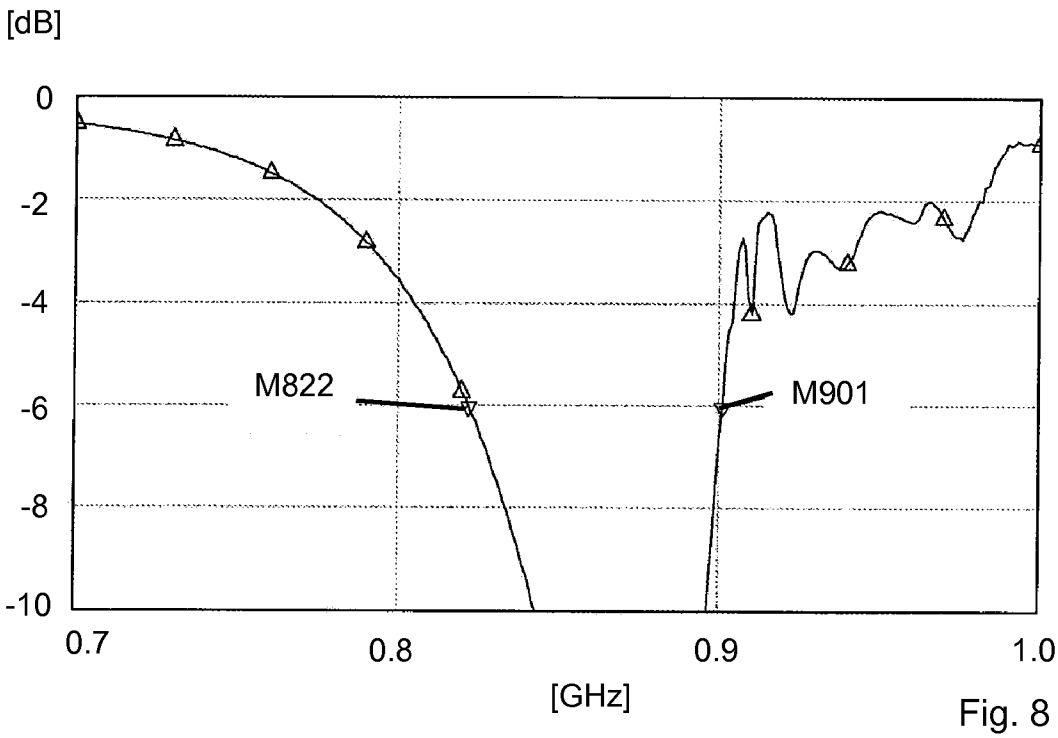

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/055549

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01Q1/24 H01Q21/28 H04B7/02
ADD. H04B7/08

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 H04B

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 763 152 A1 (CASIO HITACHI MOBILE COMM CO [JP]) 14 March 2007 (2007-03-14) * abstract paragraphs [0002] - [0011] paragraphs [0028], [0029], [0031] - [0035], [0042], [0045], [0046] paragraphs [0048] - [0057], [0061], [0062], [0067] paragraphs [0087], [0090], [0093] figures 1,2A,2B,3,4A,4B,4C,5	1-9
X	JP 2004 072605 A (SONY ERICSSON MOBILE COMM JP) 4 March 2004 (2004-03-04) * abstract figures 20,21	1-9

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
26 August 2010	02/09/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kruck, Peter

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/055549

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 03/049321 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; BERGERVOET JOZEF R M [NL]; DOLMAN) 12 June 2003 (2003-06-12) * abstract page 1, line 8 - page 5, line 21 figures 1,2	1-4,6-9
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2010/055549

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