Title: ANTENNA DEVICE AND FOLDABLE ELECTRONIC DEVICE COMPRISING SUCH AN ANTENNA DEVICE

Abstract: The present invention relates to an antenna device for a foldable electronic device for operation in at least one frequency band, wherein the foldable electronic device is equipped with two parts foldable against each other along one side through one or more hinges. The antenna device comprises a feeding arrangement arranged across a gap between the two parts for providing resonance based on the dimensions of the gap, wherein a feed is connected to a first part of said two parts and a ground is connected to a second part of said two parts.
ANTENNA DEVICE AND FOLDABLE ELECTRONIC DEVICE
COMPRISING SUCH AN ANTENNA DEVICE

FIELD OF INVENTION

The present invention relates generally to antenna devices and more particularly to an antenna device for a foldable electronic device, such as a portable computer.

BACKGROUND

Internal antennas have been used for some time in foldable electronic devices, such as portable computers. Internal antennas in portable computers are often arranged in available space, such as in non-metallic parts around the display or around the keyboard.

Full metal cover portable computers have now been introduced into the market, making it more difficult to provide antennas therefore. Some solutions include removing a part of the full metal, to be able to arrange an internal antenna therein, but it is thus no longer a full metal cover. Another solution includes having a common antenna arranged in a plastic part protruding out from e.g. the display part of a portable computer into the gap between the display part and the keyboard part of a portable computer. For all of these solutions a full metal cover is not really provided.
It would thus be advantageous if an antenna device could be provided for a foldable electronic device which would allow the foldable electronic device to have a full metal cover.

**SUMMARY OF THE INVENTION**

An object of the present invention is thus to provide an antenna device for a foldable electronic device, which would allow the foldable electronic device to have a full metal cover.

The present invention is based on the realization that the gap between the display part and the keyboard part of a foldable electronic device can be used as an antenna device, instead of just using that gap for positioning an antenna device therein.

According to the present invention there is provided an antenna device for a foldable electronic device for operation in at least one frequency band, wherein the foldable electronic device is equipped with two parts foldable against each other along one side through one or more hinges, said antenna device comprising a feeding arrangement arranged across a gap between the two parts for providing resonance based on the dimensions of the gap, wherein a feed is connected to a first part of said two parts and a ground is connected to a second part of said two parts, whereby the foldable electronic device can be provided with a full metal cover and the gap can be utilized as a notch or slot antenna.
Advantageously, one or more short circuits are preferably arranged across the gap, providing the possibility of the antenna device having one or more well defined frequency bands.

The feeding arrangement is preferably arranged between a short circuit across the gap and an open end of the gap, thereby arranging the antenna device as a notch antenna in the foldable electronic device. Advantageously, the feeding arrangement is preferably positioned across the gap at a predefined distance from the short circuit, which distance is selected to adjust a desired input resistance, typically 50\,\Omega.

The feeding arrangement is preferably alternatively arranged between two short circuits across the gap, thereby arranging the antenna device as a slot antenna in the foldable electronic device.

By preferably arranging a short circuit through a hinge, already available structure can be utilized.

The foldable electronic device is preferably a full metal cover, fully utilizing the advantage of the present invention.

The foldable electronic device is preferably a portable computer having a first part including a display and a second part including a key board.

The feeding arrangement preferably comprises at least two feeds connected to the first part, whereby the antenna device can be provided with multiple frequency bands or MIMO for a single band.
The antenna device is preferably arranged with a common short circuit for the two feeds.

Further features and advantages of the present invention will be evident from the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become more fully understood from the detailed description of embodiments given below and the accompanying figures, which are given by way of illustration only, and thus, are not limitative of the present invention, wherein:

Fig. 1 schematically illustrates a foldable electronic device in an open position according to a first embodiment of the present invention.

Fig. 2 schematically illustrates a foldable electronic device in an open position according to a second embodiment of the present invention.

Fig. 3 schematically illustrates a foldable electronic device in an open position according to a third embodiment of the present invention.

Fig. 4 schematically illustrates feeding across a slot antenna.
Fig. 5 schematically illustrates feeding across a notch antenna.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, for purpose of explanation and not limitation, specific details are set forth, such as particular techniques and applications in order to provide a thorough understanding of the present invention. However, it will be apparent for a person skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed description of well-known methods and apparatuses are omitted so as not to obscure the description of the present invention with unnecessary details.

An antenna device for a foldable electric device according to a first embodiment of the present invention will now be described with reference to Fig. 1.

The antenna device is arranged in a foldable electronic device for operation in at least one frequency band. The foldable electronic device is here a portable computer having two parts foldable against each other along one side through one or more hinges.

The first part 1 typically includes a display and the second part 2 typically includes a keyboard, which two parts here are foldable against each other along one side through two hinges 3 and 4. The first and second parts are folded against each other in a closed
position and distanced from each other by a gap along the side with the hinges.

The antenna device comprises a feeding arrangement arranged across the gap for providing resonance based on the dimensions of the gap, wherein a feed of the feeding arrangement is connected to the first part 1 of the two parts and a ground is connected to the second part 2 of the two parts.

The antenna device further comprises one or more short circuits across the gap, here illustrated with a short circuit at each of the two hinges. This provides the antenna device with three sections along the gap: an open ended slot, or notch, between the left end of the portable computer and the left short circuit 3; a slot between the two short circuits 3 and 4, and another notch, or open ended slot, between the right end of the portable computer and the right short circuit 4. The feeding arrangement is arranged at one of the three sections along the gap.

A feeding arrangement at a slot is illustrated in Fig 4. A coaxial cable is here illustrated to show the feeding, but could alternatively e.g. be provided by a parallel flex cable. The ground shield 7 is connected to the second part 2, and the feed 8 is connected to the first part 1. Although the feed 8 has been illustrated in Fig. 4 as having a galvanic connection, the connection might alternatively be capacitive or implemented as an open-ended series stub of approximately λ/4 length. The distances 9 and 10 to the short circuits at the ends of the slot are
advantageously selected to predefined distances to adjust the input resistance to a desired value, typically $50\Omega$.

A feeding arrangement at a notch is illustrated in Fig 5. A coaxial cable is here illustrated to show the feeding, but could alternatively e.g. be provided by a parallel flex cable. The ground shield 7 is connected to the second part 2, and the feed 8 is connected to the first part 1. Although the feed 8 has been illustrated in Fig. 5 as having a galvanic connection, the connection might alternatively be capacitive or implemented as an open-ended series stub of approximately $\lambda/4$ length. The distance 11 to the open end and the distance 12 to the short circuit are advantageously selected to predefined distances to adjust the input resistance to a desired value, typically $50\Omega$. Distance 11 together with distance 12 determines the lowest-order resonant frequency ($\lambda/4$ in this case) of the antenna.

With the gap utilized as a notch or slot antenna for the portable computer the cover therefore can be made fully metalized, in the meaning that all outer parts that are not used for user interface are metalized.

For providing the antenna device with multiple frequency bands a second feed is preferably added. By advantageously having the first feed in the first notch and the second feed in the second notch a MIMO solution for e.g. 2.4 GHz WLAN may easily be provided. Each of the notch antennas may also be configured for dual band covering also e.g. BT and/or 5 GHz.
By adding a second feed-line, connected to the same port, in a single section a virtual/fictitious short circuit is created, which provides more modes or resonances to enable multi-band operations.

Although the short circuits have been illustrated as symmetrically arranged in the portable computer, and particularly coinciding with the hinges, they can be arranged in other positions as well. Further, a short circuit can be made very wide and cover much of the gap.

An antenna device for a foldable electric device according to a second embodiment of the present invention will now be described with reference to Fig. 2. This second embodiment of the present invention is identical to the first embodiment described above apart from the following.

A third short circuit 5 between the first 1 and second part 2 is added between the first 3 and second 4 short circuit, which provides the antenna device with four sections for providing resonances: two outer notches and two inner slots.

An antenna device for a foldable electric device according to a third embodiment of the present invention will now be described with reference to Fig. 3. This third embodiment of the present invention is identical to the first embodiment described above apart from the following.

A single short circuit 6 is provided between the first 1 and second part 2, which provides the antenna device
with two sections for providing resonances: two outer notches. In case both sections are utilized for providing resonance having the short circuit as a common short circuit, the $S_{21}$ coupling there between will be adequate due to large metallic portions.

It will be obvious that the present invention may be varied in a plurality of ways. Such variations are not to be regarded as departure from the scope of the present invention. All such variations as would be obvious for a person skilled in the art are intended to be included within the scope of the present invention as defined by the appended claims.
CLAIMS

1. An antenna device for a foldable electronic device for operation in at least one frequency band, wherein the foldable electronic device is equipped with two parts (1, 2) foldable against each other along one side through one or more hinges (3, 4), said antenna device comprising a feeding arrangement (7, 8) arranged across a gap between the two parts for providing resonance based on the dimensions of the gap, wherein a feed (8) is connected to a first part (1) of said two parts and a ground (7) is connected to a second part (2) of said two parts.

2. The antenna device according to claim 1, comprising one or more short circuits (3-6) across said gap.

3. The antenna device according to claim 2, wherein said feeding arrangement is arranged between a short circuit across said gap and an open end of said gap.

4. The antenna device according to claim 3, wherein said feeding arrangement is positioned across said gap at a predefined distance (12) from said short circuit.

5. The antenna device according to claim 2, wherein said feeding arrangement is arranged between two short circuits across said gap.

6. The antenna device according to any of claims 2-5, wherein a short circuit is arranged through one or more of said one or more hinges.
7. The antenna device according to any of claims 1-6, wherein said foldable electronic device has a full metal cover.

8. The antenna device according to any of claims 1-7, wherein said foldable electronic device is a portable computer having a first part including a display and a second part including a key board.

9. The antenna device according to any of claims 1-8, wherein said feeding arrangement comprises at least two feeds connected to said first part.

10. The antenna device according to claim 9, wherein said two feeds are configured to provide MIMO for said frequency band.

11. The antenna device according to claim 9 or 10, comprising a common short circuit for said two feeds.

12. A foldable electronic device having a first part including a display foldable against a second part including a key board through one or more hinges, having a gap there between, wherein said gap is utilized as an antenna device for said foldable electronic device.

13. The foldable electronic device according to claim 12, comprising an antenna device according to any of claims 1-11.

14. The foldable electronic device, according to claim 12 or 13, being a portable computer.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01Q1/24 H01Q13/10

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 practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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* Special categories of cited documents:
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**INTERNATIONAL SEARCH REPORT**

**C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT**

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