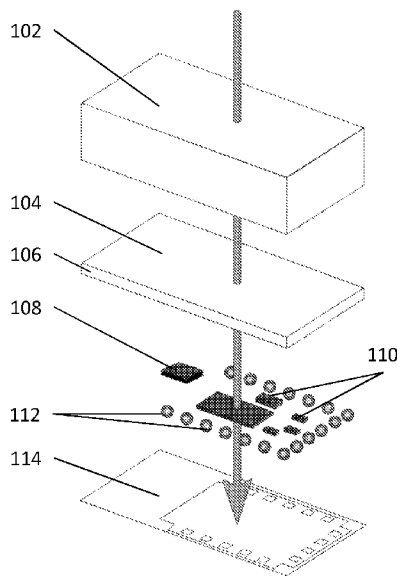




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[Continued on next page]

(54) Title: RADIO FREQUENCY MODULE AND CIRCUIT BOARD



(57) Abstract: An RF-module and a circuit board comprising an RF-module, wherein the RF-module has a sandwich structure which comprises an antenna layer(102) processed from organic substrate material, the antenna layer comprising an antenna element, a ground plane (104) below the antenna layer, a component board(106) below the ground plane, to which components are attached, e.g. by reflow soldering, the components comprising IPD-based matching and filtering circuit of the antenna (108), and connectors (112) for coupling the RF-module to a circuit board.

Fig. 1

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, — *before the expiration of the time limit for amending the
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RADIO FREQUENCY MODULE AND CIRCUIT BOARD

Technical field

The invention relates to a radio frequency (RF) module and to a circuit board comprising the radio frequency module.

Background of the invention

Radio frequency modules are known in the prior art. Radio frequency (RF) modules are small electronic devices used to transmit and/or receive radio signals between two devices.

Radio frequency (RF) modules are widely used in electronic design owing to the difficulty of designing radio circuitry. Good electronic radio design is complex because of the sensitivity of radio circuits and the accuracy of components and layouts required to achieve operation on a specific frequency. In addition, reliable RF communication circuit requires careful monitoring of the manufacturing process to ensure that the RF performance is not adversely affected. For these reasons, pre-made radio modules are often used rather than using a discrete design.

Several carrier frequencies are commonly used in commercially-available RF-modules, including those in the industrial, scientific and medical (ISM) radio bands such as 433.92 MHz, 315 MHz, 868 MHz, 915 MHz, and 2400 MHz. RF modules may comply with a defined protocol for RF communications such as Zigbee, Bluetooth low energy, or Wi-Fi, or they may implement a Proprietary protocol.

The prior art RF-module solutions require strict and complex requirements for the underlying circuit board, e.g. requirements for big external ground plane area connected to the RF-module. If e.g. external ground plane areas are not used with prior art RF-modules, receiving and transmitting frequency range of the antenna can be shifted off from the designed frequency range when the module is attached close to a ground plane or close to living tissue such as skin (skin-effect).

Summary of the invention

The solution of the present invention is a radio frequency module which is able to operate as a transceiver. The RF-module according to the invention has a sandwich structure which comprises an antenna layer processed from organic substrate material, the antenna layer comprising an antenna element. The RF-module further comprises a ground plane below the antenna layer and a component board below the ground plane, to which components can be attached e.g. by reflow soldering, the components comprising IPD-based matching and filtering circuit of the antenna. The RF-module further comprises connectors for coupling the RF-module to a circuit board.

In one embodiment of the invention, only antenna matching and filter components are implemented in the IPD to ensure small size and competitive price.

The invention relates also to a circuit board which comprises the RF-module of the invention. In one embodiment of the invention the circuit board comprises a guard ring which is connected to the ground plane of the RF-module and essentially surrounds the module when the RF-module is attached to its place on the circuit board.

With the solution of the present invention frequency range of the selective receiver and transmitter of the antenna is not essentially shifted off from the designed range even when the module is attached close to a ground plane or close to living tissue such as skin (skin-effect). If the RF-module is very close to ground plane or tissue, the amplification of the antenna can slightly decrease but the selectivity is not essentially affected and the frequency range transmitted and received by the antenna is not tuned off from the designed range. This kind of performance can't be achieved with the prior art RF-modules without large external ground planes to which the prior art RF-modules are attached.

The RF-module of the invention can be attached to any kind of generic circuit board, only the RF module footprint just under the module is specified. This is a considerable advantage compared to prior art RF-modules, e.g. prior art BLE-modules which have much stricter and much more com-

plex requirements for the underlying circuit board, e.g. requirements for big ground plane area.

Brief description of the drawings

In the following, the invention will be described in more detail by means of an embodiment example with reference to the appended drawings, in which

Fig. 1 presents an example embodiment of the RF-module and different parts of the RF-module as well as an application board to which the RF-module can be connected.

Detailed description of the invention

One example embodiment of the RF-module is illustrated in Fig. 1. The RF-module of the present invention has a sandwich structure. The antenna is arranged on top of the structure on the antenna layer 102. The antenna can be made of high performance RF material. Other components such as Radio Frequency Integrated Circuit (RFIC), Integrated Passive Devices (IPD) 108 and all other needed RF-components 110 are arranged under the antenna. RFIC and IPD blocks 108 as well as other needed RF-components 110 can be attached to a component board 106, on the opposite side of the antenna. The component board can be e.g. a circuit board such as a FR-4 circuit board to which components are attached. The IPD 108 of the RF-module comprises an antenna matching circuit as well as filter components. The whole structure stands on connectors 112 e.g. BGA balls, leaving the RFIC, IPD 108 and RF-components 110 on the top side of the module. The RF-module can be attached to any generic electric board or circuit board with the connectors 112.

The antenna can be a separate component made of high performance RF material like for example RT/Duroid 5870 or Neltec 4 ($\epsilon_r=2.33$, $\tan\delta=0.001$). When the antenna is arranged as a separate component, like in the embodiment of Figure 1, the advantage is that good antenna performance as well as competitive price can be reached.

The antenna of the RF-module according to the invention needs a matching network to drive the small and highly reactive antenna impedance to e.g. 50Ω standard impedance. This matching can be implemented e.g. by using series capacitor and parallel inductor topology. The antenna matching circuit is implemented on the IPD platform. In addition to the antenna matching components, RF-filter is integrated on the IPD.

The IPD in according to one embodiment of the invention can be based on thin film technologies over the quartz or silicon wafers. This solution is cost effective and the line widths and tolerances are excellent. The IPD module integration can be done using flip-chip bonding which provides higher I/O density, RF properties and better mass market manufacturing potential than wire bonding.

In one embodiment of the invention, only antenna matching and filter components are implemented in the IPD to ensure small size and competitive price. The size of the IPD block which includes the antenna matching e.g. to 50Ω as well as filtering can be e.g. $1.5 \times 1.2 \text{ mm}$. The total size of the RF-module can be e.g. $7.5 \times 13.5 \times 4.5 \text{ mm}$.

The RF-module can be e.g. a Bluetooth low energy (BLE) RF-module, Bluetooth-, Zigbee-, RFID- or Wi-Fi-module, or it may implement a proprietary protocol. The RF-module can operate e.g. in the 2.4GHz ISM band, more specifically from 2.400 to 2.484 GHz or other ISM radio bands such as 433.92 MHz, 315 MHz, 868 MHz, 915 MHz, 5 GHz, 5.8 GHz or other radio bands.

The special feature of this antenna and RF-module is that it can operate well on any kind of generic board structure; only the module footprint just under the module is specified. So with the RF-module of this invention there are no size specifications, no external ground plane or ground plane opening specifications for the generic board. This is an advantage, since the prior art RF-modules need a special opening area or a certain size of external ground plane on the generic board.

In one embodiment of the invention the RF-module is connected to a circuit board 114 which comprises a guard ring which is connected to the ground plane of the RF-module and essentially surrounds the RF-module.

In one embodiment the performance of the RF-module according to the invention can be even further be increased by having a ground plane in the circuit board to which the RF-module is connected.

Although exemplary embodiments of the present invention have been described with reference to the attached drawings, the present invention is not limited to these embodiments, and it should be appreciated to those skilled in the art that a variety of modifications and changes can be made without departing from the spirit and scope of the present invention. Embodiments described in the description in combination with other embodiments can be also used as separate embodiments.

Claims

1. An RF-module **characterized** in that the RF-module has a sandwich structure which comprises:

an antenna layer (102) processed from organic substrate material, the antenna layer comprising an antenna element

a ground plane (104) below the antenna layer,

a component board (106) below the ground plane, to which components are attached, e.g. by reflow soldering, the components comprising IPD-based matching and filtering circuit of the antenna (108), and connectors (112) for coupling the RF-module to a circuit board.

2. An RF-module according to claim 1, **characterized** in that the connectors (112) are flip chip soldering elements.

3. An RF-module according to claim 1 or 2 **characterized** in that the antenna element is a loop antenna or a monopole antenna.

4. An RF-module according to any preceding claim **characterized** in that the antenna layer (102), the ground plane (104) and the component board (106) form an integrated structure.

5. An RF-module according to any preceding claim **characterized** in that RF-module is Bluetooth-, Bluetooth low energy, Zigbee-, RFID- or Wi-Fi-module.

6. A circuit board **characterized** in that the circuit board (114) comprises the RF-module according to any claims 1 – 5.

7. A circuit board according to claim 6 **characterized** in that the circuit board (114) further comprises a guard ring which is connected to the ground plane of the RF-module and arranged essentially to surround the RF-module.

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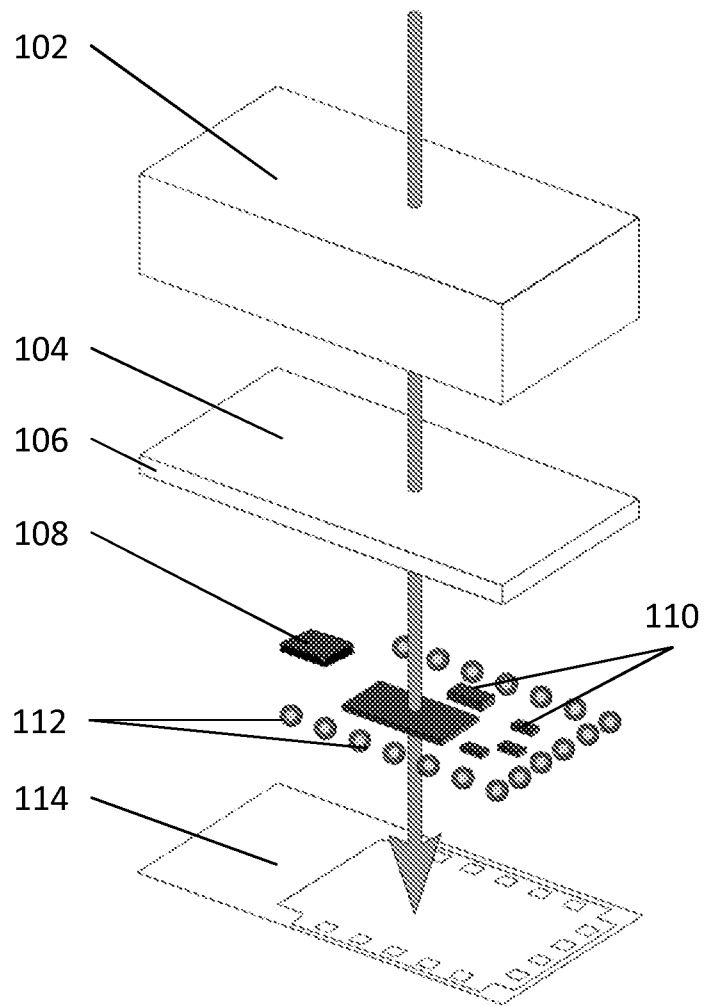


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER

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: H04B, H01Q, H05K

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

FI, SE, NO, DK

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

EPO-Internal, WPIAP

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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 Further documents are listed in the continuation of Box C.
 See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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