A Novel Integrated Dual-mode RF Front-end module for Wi-Fi and Bluetooth Applications

Dong-Ho Kim*[1,2], Dongsu Kim[1], Jun-Chul Kim[1], Jong-Chul Park[1], and Chong-Dae Park[2]

[1] System Packaging Research Center,
Korea Electronics Technology Institute,
68 Yatap-Dong, Bundang-gu, Seongnam-si, Gyeonggi-do, 463-816, Korea

[2] Electronics Engineering, Myongji University,
San 38-2 Namdong, Cheoin-gu, Yongin-si, Gyeonggi-do, 449-728, Korea

*k-dongho@mju.ac.kr

***Abstract*— In this paper, a novel integrated dual-mode RF FEM for Wireless Fidelity (Wi-Fi) and Bluetooth application is realized by low temperature co-fired ceramic (LTCC) technology. The proposed dual-mode RF FEM has 4 ports and consists of a novel selectable filter, which are fully embedded in the LTCC substrate, and 3 PIN diodes at each port except antenna port for shortening to the ground or not. This selectable filter structure can be applied for either Tx and Rx path for Wi-Fi or BT path by simply making two ports to be shorted to the ground. The fabricated dual-mode RF FEM has 7 pattern layers including 2 ground layers and it occupies less than 3.0 mm × 3.0 mm × 0.308 mm. It can be low-loss and low-cost solution by removing MMIC SP3T switch in series connection.**

***Index Terms* — Bluetooth, LTCC, PIN diode, RF front-end module, selectable filter, Wi-Fi.**

I. INTRODUCTION

In recent years, wireless communication system area has expanded vary rapidly. Current trends in wireless communication system are miniaturization, high integration, multi-band/multi-mode operation. Among several technologies to realize compact and high integrated RF components and modules, LTCC is one of the most promising technologies. For this reason, many passive components and RF front-end modules (FEMs) using the LTCC technology have been reported [1]-[4]. Especially, coexisting wireless frequency for multi-mode, such as Wi-Fi and Bluetooth(BT), is major trend in modern wireless communication system.

In this paper, a novel integrated dual-mode selectable filter for BT and Wi-Fi combination systems is designed and implemented. The proposed selectable filter is operated by simply making two of the output ports to be shorted to ground. Therefore, this proposed filter structure can be adopted for either Tx and Rx path for Wi-Fi or BT path without any modification. The realization of the proposed selectable filter is done by LTCC technology.

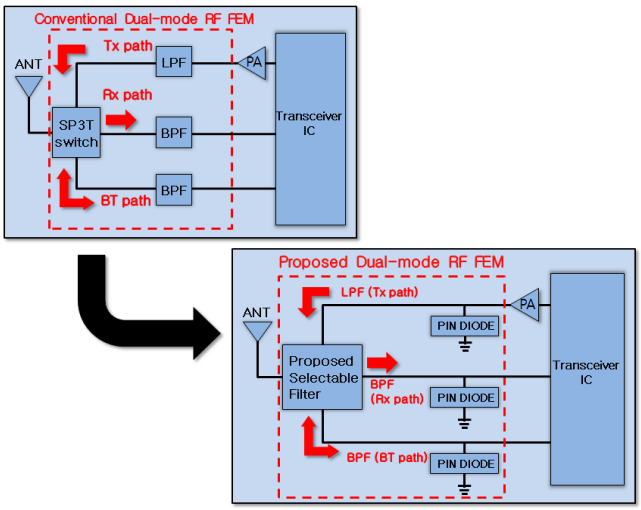


Fig. 1. Block diagram of novel integrated dual-mode RF FEM for Wi-Fi and Bluetooth.

Based on the proposed selectable filter, a novel dual-mode RF FEM is designed for Wi-Fi and BT application. The conventional dual-mode RF FEM for Wi-Fi and BT application is composed of an SP3T switch for selecting Tx, Rx and BT path, LPF and two BPFs. However, the proposed dual-mode RF FEM can be realized by the proposed selectable filter with 3 PIN diodes at each output port except common antenna port for shortening to the ground or not, as illustrated in Fig. 1. All passive components except PIN diodes and DC block capacitors for PIN diode operation are fully embedded in the LTCC substrate. Compared to the conventional approach, the proposed dual-mode RF FEM can play a role of a LPF or a BPF for the same frequency band with very low insertion loss by removing MMIC SP3T switch in series connection and fairly high isolation between the LPF and two BPFs.

II. Design of Proposed Dual-mode Selectable Filter

Fig. 2 shows the proposed dual-mode selectable filter for Wi-Fi and BT system. It is designed to operate in three different modes of either a LPF or two BPFs by making two of the output ports to be shorted to ground. It consists of common elements (L_{S1}, L_{S2}, C_{P1}), a LPF part (L_{S3} and C_{P2}), and two BPFs part (C_{S1}, L_{S4}, L_{S5}, C_{P3} and C_{P4}). An LC lumped element approach is employed in this work.

The proposed dual-mode selectable filter has three different characteristics, as shown in Fig. 2. When the output ports (port 3 and port 4) of two BPFs are shorted to the ground, the BPFs part operates as a shunt resonator, as shown in Fig. 2(a). As a result, the proposed filter provides characteristic of a LPF for Wi-Fi. On the other hand, when the output port (port 2 and port 4) of the LPF part and BPF of BT path part is shorted to ground, it operates as a shunt inductor, as shown in Fig. 2(b). As a result, the proposed filter provides characteristic of a BPF for Wi-Fi. In the same method, when the output port (port 2 and port 3) of the LPF part and BPF of Rx path part is shorted to ground, it provides characteristic of a BPF for Bluetooth, as shown in Fig. 2(c). All elements for each modes are same except shortening ports.

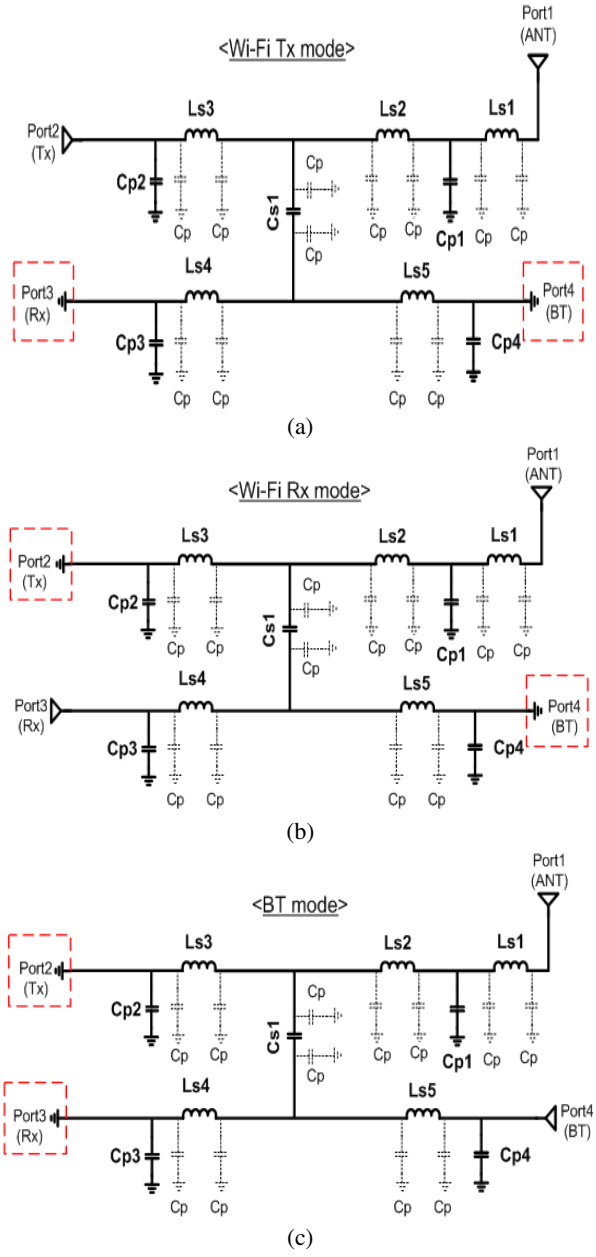


Fig. 2. Schematic diagram of the proposed dual-mode selectable filter. (a) Tx path for Wi-Fi, (b) Rx path for Wi-Fi, (c) BT mode.

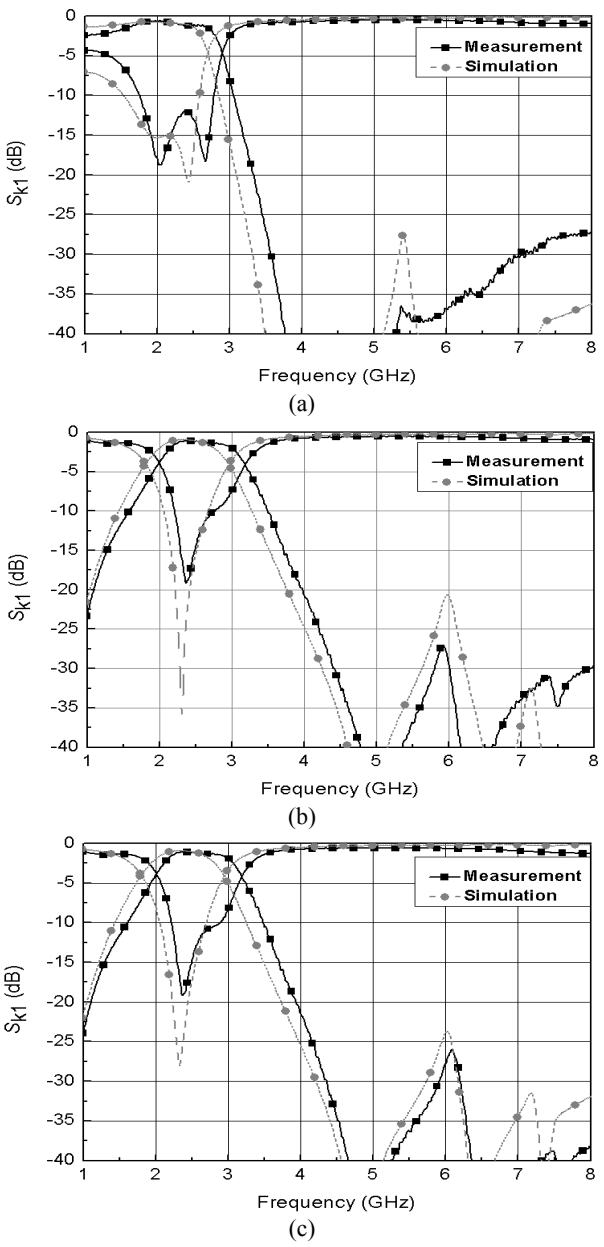


Fig. 3. Measured and simulated performance of the proposed dual-mode selectable filter. (a)Tx path for Wi-Fi, (b)Rx path for Wi-Fi, (c)BT path.

There are several small-value (0.2 ~ 0.4 pF) parasitic capacitors C_P which are generated by inductor- or capacitor-pattern and ground plane. Because these capacitors break the matching characteristic and degrade the overall electrical performance, we should consider these unwanted components during design.

Fig.3 shows the comparison simulated results and measured results. The measurement was carried out using 2-port vector network analyzer 37397C. In case of Tx path for Wi-Fi, it has an insertion loss of less than 1.19 dB, a return loss of more than 12.2 dB, and the second harmonic level of more than 42.5-dB in the frequency range of 4.8 ~ 5.0 GHz. In case of Rx path for Wi-Fi, the insertion loss and return loss are less than 1.13 dB and more than 14.6 dB, respectively. In case of BT path, it has an insertion loss of less than 1.13 dB and a return loss of more than 14.8 dB at 2-GHz band.

III. Dual-mode RF FEM with the Selectable Filter

The schematic of a dual-mode RF FEM with a proposed selectable filter is shown in Fig. 4. It is composed of proposed selectable filter, 3 PIN diodes (HVD 142 from Hitachi) as switching elements, 3 DC block capacitors, 3 RF choke inductors and 3 bypass capacitors. On the top of the LTCC substrate, 3 PIN diodes and 3 DC block capacitors are mounted.

When PIN diode D1 is turned off and PIN diode D2 and diode D3 are turned on, the RF FEM operates as Tx mode for Wi-Fi. In the same method, when PIN diode D1 and diode D3 are turned on and PIN diode D2 is turned off, the RF FEM operates as Rx mode for Wi-Fi. Similarly, when PIN diode D1 and diode D2 are turned on and PIN diode D3 is turned off, the RF FEM operates as BT mode for Bluetooth.

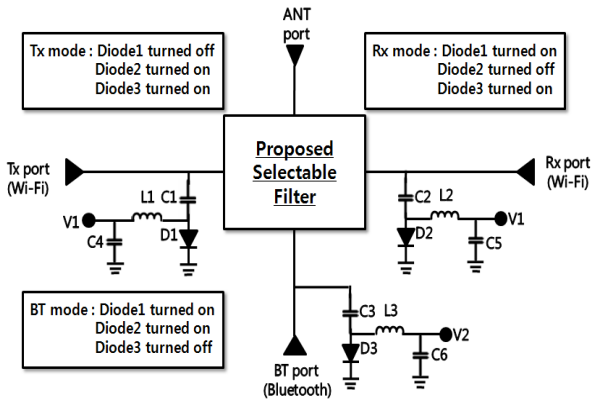
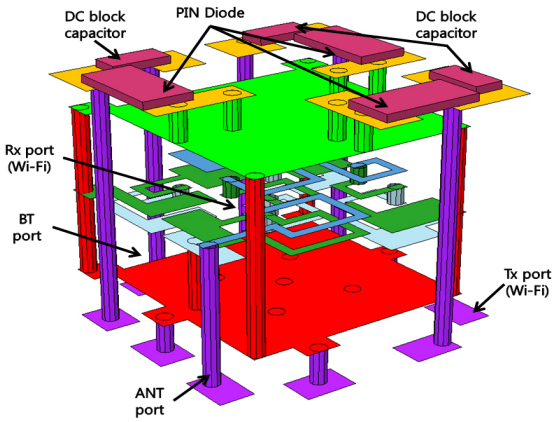
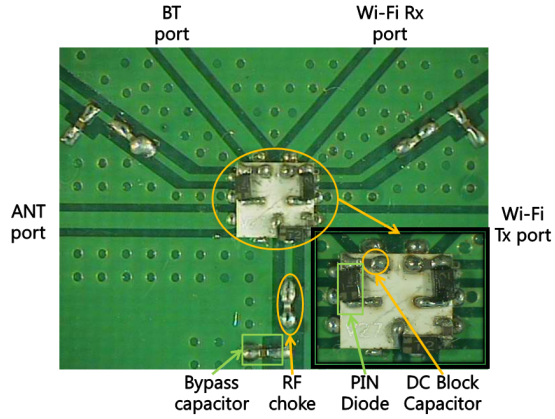


Fig. 4. Schematic of dual-mode RF FEM with selectable filter for Wi-Fi and Bluetooth system.

Fig. 5 illustrates three dimensional view and photograph of the proposed dual-mode RF FEM. The LTCC substrate which used in manufacturing the proposed RF FEM had dielectric constant 9.0, loss tangent of 0.005 and thickness of 40 μm. After co-firing, each sheet thickness is shrunk to 22 μm. The number of pattern layer in the fabricated RF FEM is 7 including 2 inner grounds, and its thickness is 308 μm. The overall size of the module is less than 3.0 mm × 3.0 mm.



(a)



(b)

Fig. 5. Dual-mode RF FEM. (a) Three-dimensional view, (b) Photograph of the fabricated module.

IV. Measured Performance of RF FEM

The measured result of the dual-mode RF FEM is shown in Fig. 6. In case of Tx path for Wi-Fi, the LPF has an insertion loss of less than 1.27 dB, and a return loss of more than 19.9 dB. The second harmonic suppression is more than 34-dB in the frequency range of 4.8 ~ 5.0 GHz. In case of Rx path for Wi-Fi, the BPF provides an insertion and return losses are less than 1.56 dB and better than 17.1 dB, respectively. In case of BT path, it has an insertion loss of less than 1.68 dB, and a return loss of more than 15.7 dB.

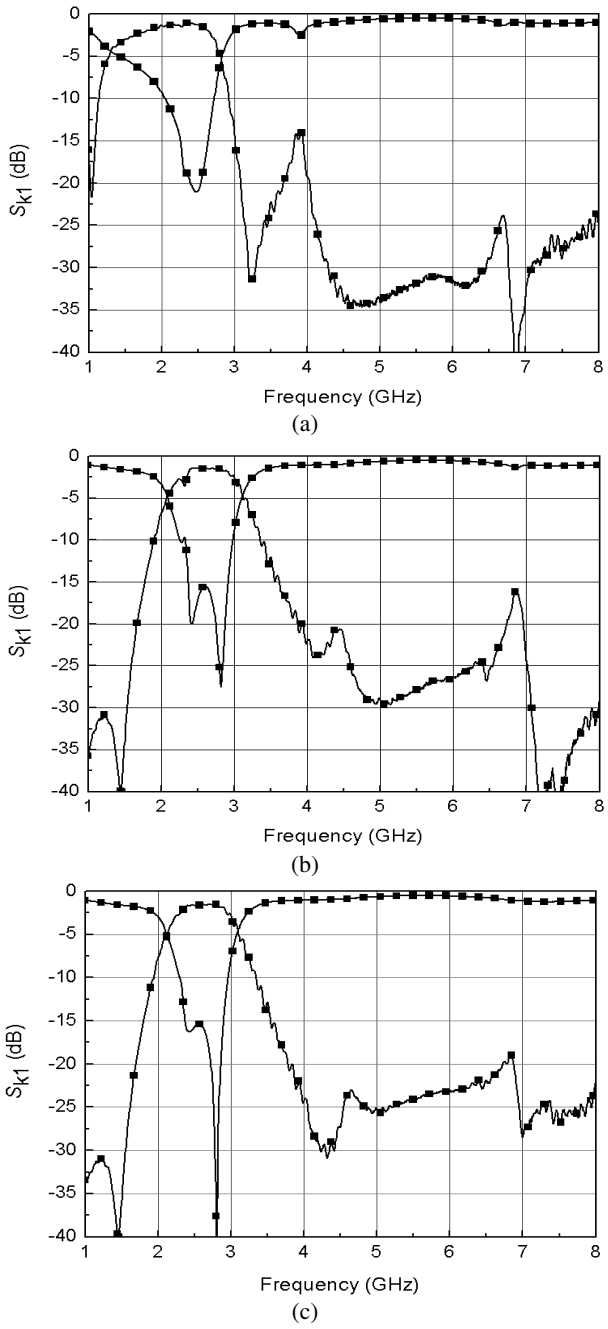


Fig. 6. Measured performance. (a) Tx mode, (b) Rx mode, (b) BT mode.

V. Conclusion

In this paper, the compact and novel integrated dual-mode RF FEM for Wi-Fi and Bluetooth operation has been designed and implemented. All passive components in the proposed selectable filter are fully embedded in the substrate. By simply making output ports to be shorted to ground, Tx- or Rx-mode for Wi-Fi or BT mode for Bluetooth operation can be selected. The simulated and measured results of the proposed selectable filter were in good agreement. The RF FEM was realized by the selectable filter with 3 PIN diodes at each output port for selecting Tx- or Rx- or BT mode. It provided relatively low loss, high return loss, and high isolation in each operation. The overall size of the dual-mode RF FEM is only 3.0 mm × 3.0 mm × 0.308 mm.

References

[1] D. H. Kim, D. Kim, J. I. Ryu, J. C. Kim, J. C. Park, and C. D. Park, "A novel integrated Tx-Rx diplexer for dual-band WiMAX system," *2010 IEEE MTT-S Int. Microwave Symp. Dig.,* pp. 1736-1739, May 2010.

[2] D. H. Kim, D. Kim, J. C. Kim, J. C. Park, and C. D. Park, "Design of selectable low- and bandpass filter for 2.4 GHz applications," *Electronics Letters,* vol. 46, No. 25, pp. 1699-1700, Dec. 2010.

[3] S. Sakhnenko, D. Orlenko, B. Vorotnikov, O. Aleksieiev, P. Komakha, and P. Heide, "Ultra-low-profile small-size LTCC front-end module for WLAN applications based on a novel diplexer design approach," *2009 IEEE MTT-S Int. Microwave Symp. Dig.,* pp. 609-612, June 2009.

[4] D. Kim, D. H. Kim, C. D. Park, J. I. Ryu, J. C. Kim, and N. K. Kang, "LTCC-based triplexers for WiMAX front-end modules," 2008 *IEEE EDPAS Dig.*, pp. 190-193, Dec. 2008.

[5] A. Yatsenko, D. Orlenko, S. Sakhnenko, G. Sevskiy, and P. Heide, "A small-size high-rejection LTCC diplexer for WLAN applications based on a new dual-band bandpass filter," *2007 IEEE MTT-S Int. Microwave Symp. Dig.,* pp. 2113-2116, June 2007.

[6] M. Buchsbaum, C. Korden, E. Leitgeb, and H. Faulhaber, "Design of a high integrated triplexer using LTCC technology," *2006 IEEE MTT-S Int. Microwave Symp. Dig.,* pp. 378-381, June 2006.

[7] Y. Lin, C. Liu, K. Li, and C. Chen, "Design of an LTCC tri-band transceiver module for GPRS mobile applications," *2004 IEEE MTT-S Int. Microwave Symp. Dig.*, pp. 633-636, June 2004.