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WiMAX 응용을 위한 결합 공진기 기반의 PCB 내장형 평형신호 듀플렉서의 설계

박주용, 박종철, 박재영
마이크로/나노 소자 및 패키징 연구실, 전자공학과 광운대학교, 서울

Design of PCB Embedded Balanced-to-unbalanced WiMax Duplexer Using Coupled LC Resonators

Ju Y. Park and Jong C. Park, Jae Y. Park
Micro/Nano Devices & Packaging Lab. Department of Electronic Engineering, Kwangwoon University, Seoul

Abstract - In this paper, PCB embedded balanced-to-unbalamced duplexer using coupled LC resonator was introduced for low cost dualband WiMax front-end-module application. In order to obtain the function of bandpass filter and balun transformer, proposed duplexer was configured by using magnetically coupled LC resonator. Out-of-band suppression was enhanced by applying two m-Derived transform circuits to obtain transmission zeros at 2GHz and 4.8GHz. In order to reduce the size of embedded duplexer, BaSrTiO3 (BST) composite high Dk RCC film was applied to improve the capacitance density. This high Dk film provided the capacitance density of 12.2 pF/mm2. The simulation results shows that fabricated duplexer had an insertion loss of 2.9dB and 5.5dB and return loss of 15dB and 16dB for 2.5GHz~2.6GHz and 3.5GHz~3.6GHz, respectively. The maximum magnitude and phase imbalance were 0.01dB and 0.17dB, and 1degree and 2degree in its passband, respectively. The out-of-band suppression was observed approximately 29dB and 40dB below 1.9GHz and over 4.5GHz, respectively. It has a volume of 6 mm × 7 mm × 0.7 mm (height).

1. Introduction

Recent wireless communication systems, such as Wireless LAN, WiMAX and etc, are using multiple frequency to ensure quality of service and maximum compatibility with various networks and requiring smaller size and low cost. These requirements are leading the increase of complexity in RF front-end-module (FEM) as shown Fig. 1.

The advances in integration technology introduce the higher level of system integration such as, system on a package (SOP) and system on a chip (SOC). Wireless and mobile communication systems are using miniaturized Radio Frequency (RF) module to satisfy low-cost and compact size requirements. Especially, low temperature co-fired ceramic (LTCC) is the prevalent choice for the implementation of these RF module. However, ceramic components have cost and reliability issues due to shrinking problems, CTE mismatch, small manufacturing area [1].

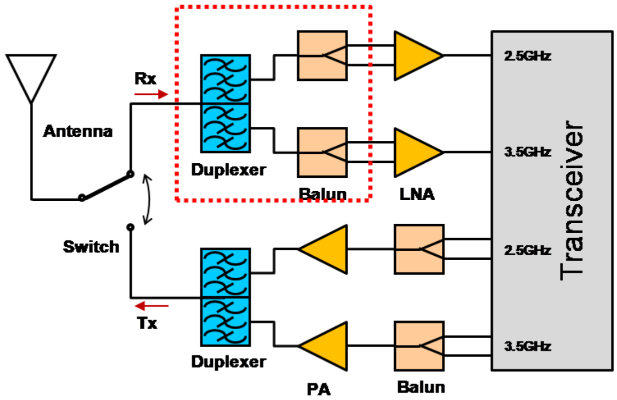
This paper proposed the design of balanced-to-unbalanced duplexer for low cost WiMax RF FEM embedded into multi-layered PCB with BST composite high Dk RCC film. In order to obtain the function of duplexer and balun transformer, two balanced-to-unbalanced filter was combined with impedance matching circuit. Furthermore, m-derived transform section was applied to improve out-of-band suppression. Proposed duplexer was designed to be embedded into 8-layered PCB. In order to reduce the size of embedded duplexer, BST composite high Dk RCC film was applied to archive compact sized embedded capacitor.

2. Design and Simulation

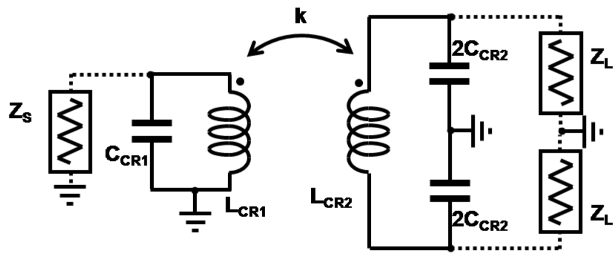
2.1 Balanced-to-unbalanced filter

The proposed duplexer consists of two balanced-to-unbalanced filter which was originated from balun transformer embedded into 8-layered PCB substrate by using coupled LC resonator as shown in Fig. 2. It's assumed that these three resonators have same resonant frequency. As shown in following equations, the fractional bandwidth (FBW) are defined by following equations [2].

$$\omega_0 = \frac{1}{\sqrt{C_{CR1}L_{CR1}}} = \frac{1}{\sqrt{L_{CR2}C_{CR2}}} \tag{1}$$



<Fig. 1> Block diagram of dualband WiMax front-end



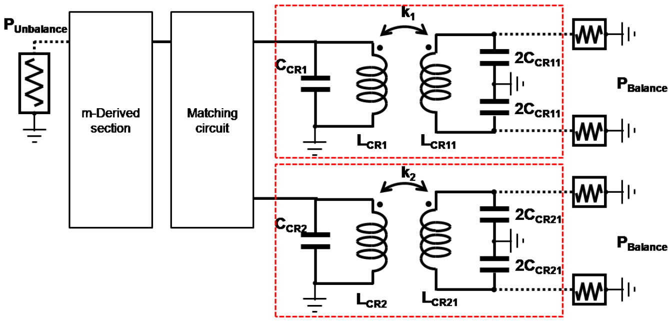
<Fig. 2> Balun transformer using coupled LC resonator

$$FBW \propto k \tag{2}$$

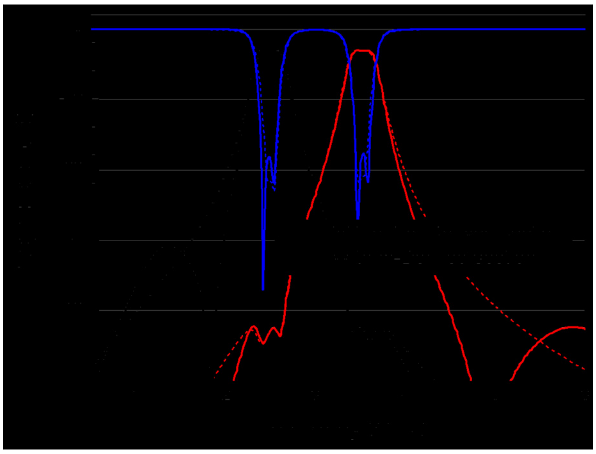
2.2 Design and Simulation of duplexer

As shown in Fig. 3, balanced-to-unbalanced filters were utilized for proposed duplexer. m-derived transformer was applied to improve the out-of-band suppression. Proposed duplexer was optimally designed 8-layered PCB with BST composite high Dk RCC film as shown in Fig. 4. In order to obtain the component values for duplexer, embedded inductors were implemented on 1st layer and embedded capacitors were formed on 2nd to 3rd layer by using high Dk film. The geometry parameters were first calculated and optimized by using 3D EM simulator. In particular, the space and width of three embedded inductors and the electrode size of the embedded capacitor were carefully optimized and interconnected, since the proposed balun was the most sensitive to their component values. Fig. 5 shows the 3D schematic drawing of proposed filter to be embedded into organic package substrate.

Fig. 6 and 7 show simulation results of fully embedded unbalanced-to-balanced duplexer. The simulation of duplexer shows an insertion loss of 2.9dB and 5.5dB, return loss of 15dB and 16dB in the operating frequency ranged from 2.5 ~ 2.6 GHz and 3.5 ~ 3.6 GHz, respectively.

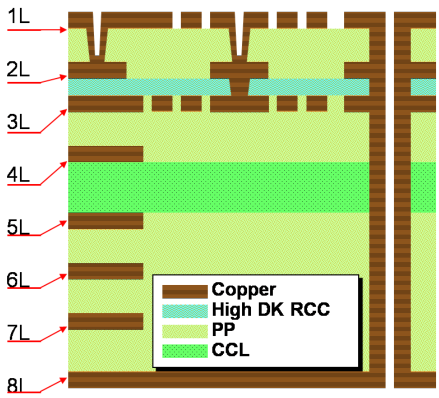


(a)

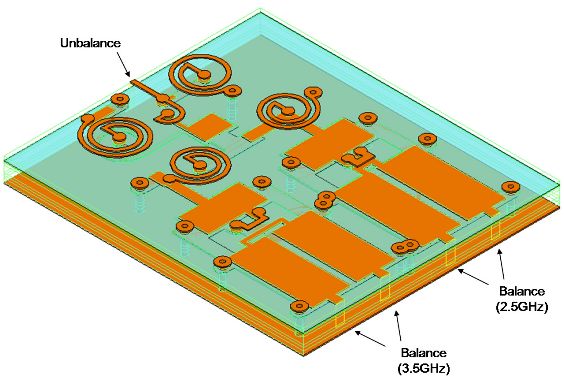


(b)

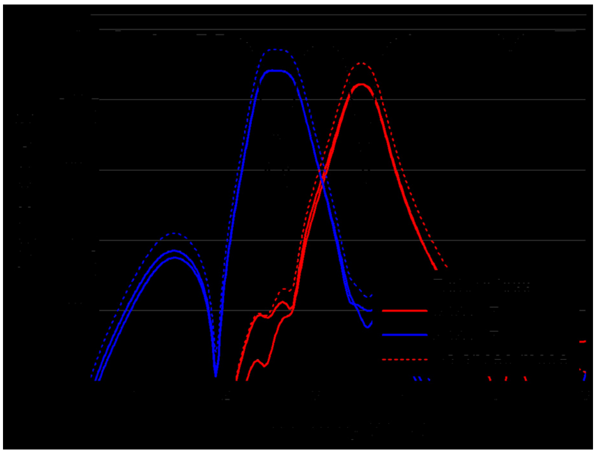
<Fig. 3> Proposed unbalanced-to-balanced duplexer circuit (a) and frequency response (b)



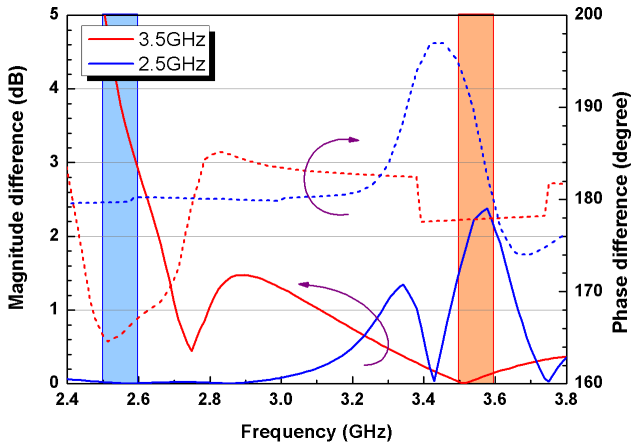
<Fig. 4> Cross-section of 8-layered PCB



<Fig. 5> 3D structure for EM simulation



<Fig. 6> Frequency response of proposed duplexer



<Fig. 7> Phase and magnitude imbalance characteristic

As shown in Fig. 7, the simulated magnitude difference are 0.01dB and 0.17dB and phase imbalance of balanced ports are 1degree and 2degree in passband for 2.5GHz and 3.5GHz, respectively. The measured out of band rejections are 29dB below 1.9 GHz and 40dB at 4.5GHz.

3. Conclusion

In this paper, unbalanced-to-balanced duplexer has been newly designed by embedding all the passive lumped elements into a PCB (Printed Circuit Board) with high dielectric composite film layer. The proposed duplexer was consisted of two unbalanced-to-balanced filter, in order to obtain bandpass transmission response at 2.5GHz and 2.5GHz. The out-of-band rejection was also improved by applying m-derived transformer. The proposed duplexer was extremely miniaturized by applying BST composite RCC film. Simulation results show that proposed duplexer has good band selectivity with function of balun transformer. In the near future, this proposed duplexer will be fabricated and characterized. This proposed duplexer might be useful for advanced wireless communication systems with small size/volume, low cost, and high performance.

[참 고 문 헌]

[1] R. Wu, et al., "High Performance and Compact Balanced-Filter Design for WiMAX Front-End Modules (FEM) Using LCP-Based Organic Substrates," *IEEE MTT-S Int. Microwave Symp.*, pp.1619-1622, 2007.

[2] J. Park, and J. Y. Park, "FR-4 Embedded Wideband Micro-balun with Coupled LC Resonators," *Proc 38th European Microwave Conf.*, pp. 333-336, 2008.