2007년도 대한전기학회 하계학술대회 논문집 2007. 7. 18 - 20

유기기판에 내장된 인덕터의 커플링을 이용한 광대역 LC 발룬의 설계

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Design of Inductive coupled wideband LC Balun Embedded Into Organic Substrate

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Abstract - In this paper, inductive coupled LC balun has been designed and simulated for embedding into an organic packaging substrate. Inductive coupling method was applied to obtain wide band characteristics, and high dielectric film was utilized to reduce a size of the balun. The proposed balun has a novel scheme which consists of three embedded LC resonators with inductive coupling. This proposed balun has relatively small inductance and capacitance values which can be easily embedded into the organic packaging substrate. Furthermore, it has a good phase imbalance characteristic. The simulated results of proposed balun are an insertion loss of 1.2 dB, a return loss of 10 dB, a phase imbalance of 1 degree at frequency bandwidth of 750 MHz ranged from 1.8 GHz to 2.55 GHz, respectively. This balun has an area of 2mm×3.5mm×0.66mm (height).

1. Introduction

Balun (balanced-to-unbalanced) is a transformer converting a single ended signal to a differential signal and vice versa. Many microwave components and modules which include power amplifiers (PA), low noise amplifiers (LNA), balanced mixers, and balanced filters use balanced inputs and outputs to reduce noise and even order harmonics at their dynamic range [1-2]. As wireless communication systems are recently being integrated and getting more complex for multi-functionality. wideband balun is being widely investigated for these multiband systems.

There are three different baluns which are coil-type, distributed-type, and lumped-type. The distributed-type balun is the most popular because it has a sufficiently large bandwidth and reasonable phase difference and power distribution. But This balun consists of quarter-wave length coupled lines which occupy large area at low frequency band. Many researches have been performed to obtain low cost and small size/volume. In particular, Marchand balun is the most attractive one which is fabricated by using low temperature co-fired ceramic (LTCC) technology [3-4]. However, the LTCC technology has some limitations such as high temperature processes and small area manufacturing. On the other hand, the lumped-type balun like lattice-type LC balun, is being adopted in microwave monolithic integrated circuit (MMIC) processes for small size and volume [5]. But it is not easy to maintain both 180° phase difference and identical magnitude of two balanced signals. To overcome these drawbacks, many studies have been performed [6-8]. In order to improve their performance characteristics, number of the lumped LC elements should be increased. However, if the number of elements are increased, it is difficult to be integrated or embedded onto or into a small package substrate and insertion loss is also increased.

The proposed balun consists of two synchronously tuned resonators with magnetic coupling which have been applied for band pass filter by using three LC resonators [9]. These inductors and capacitors have relatively small values of inductance and capacitance to be easily embedded or integrated into the substrate. DC signal can be blocked from the balanced port to the unbalanced port and vice versa, since the three resonators are not directly connected each other. This proposed balun has been well designed and simulated to be embedded into low cost organic packaging substrate with high DK film.

2. Design and Simulation

2.1 Design

As shown in Figure 1, the proposed balun consist of two asynchronously tuned resonators that are coupled magnetically due to the mutual inductance (M) which have been applied for band pass filters. L and C are the self inductance and self capacitance, respectively, and M is the mutual inductance. The resonant frequency of uncoupled resonator is given as

$$f_o = \frac{1}{2\pi\sqrt{(LC)}} \tag{1}$$

These resonant frequencies of the balun circuit shown in Figure 1 are

$$f_1 = \frac{1}{2\pi\sqrt{(L-M)C}} \tag{2}$$

$$f_2 = \frac{1}{2\pi\sqrt{(L+M)C}} \tag{3}$$

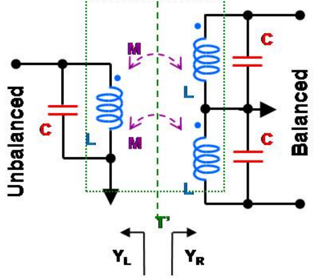
The magnetic coupling coefficient (K_m) is defined by the above frequency parameters as

$$K_m = \frac{f_2^2 - f_1^2}{f_2^2 + f_1^2} \tag{4}$$

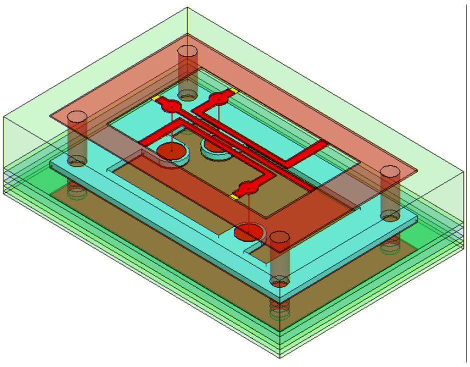
By substituting equations (2) and (3) into (4), the magnetic coupling coefficient is obtained as

$$K_m = \frac{M}{L} \tag{5}$$

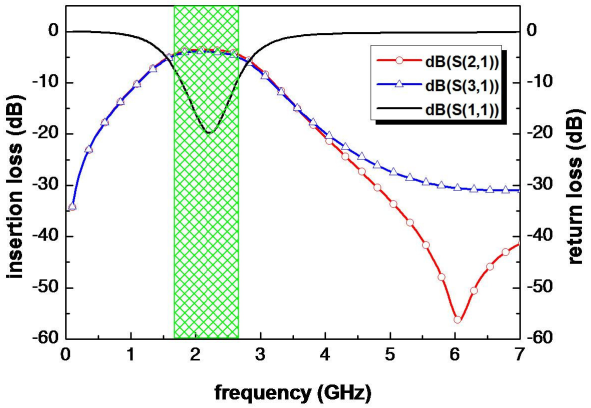
The coupling coefficient is the ratio of the coupled magnetic energy to the average stored energy of the uncoupled single resonator. This is the most important parameter because the operating bandwidth and insertion loss are dependent on the coupling coefficient.



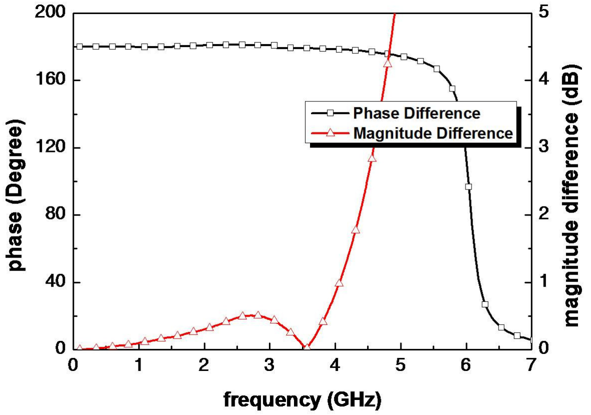
<Figure 1> A lumped element circuit drawing of proposed LC balun.



<Figure 2> 3D schematic drawing of proposed LC balun.



<Figure 3> Simulated insertion and return losses of proposed inductive coupled LC baluns embedded into organic substrate.



<Figure 4> Simulated phase and magnitude imbalances of proposed inductive coupled LC baluns embedded into organic substrate.

As shown in Figure 2, the proposed inductive coupled LC baluns have optimally been designed for being embedded into the 8-layered organic packaging substrate. The 8-layered organic substrate is comprised of a prepreg, high DK resin coated copper film, and copper clad laminate. The PP, CCL, and High DK RCC materials have different relative dielectric constant of 4.1, 4.5, 23 and loss tangent of 0.02, 0.02, and 0.027, respectively. The second layer is utilized for making MIM capacitors with high capacitance density. And three embedded inductors are implemented by using copper film formed onto the first layer. The self inductance value is calculated by using Grover's formulation [10].

The optimally designed values of the embedded inductors and capacitors for the proposed balun are 1.2nH and 4.5pF, respectively. The magnetic coupling coefficient is approximately 0.3 to get enough bandwidth range from 1.8GHz to 2.55GHz.

The length of the embedded inductor is approximately 1300μm. The MIM capacitor has a circular shaped top electrode with a diameter of 450μm. These geometry parameters are first calculated by using the above formulas and optimized by using 3D EM simulator. In particular, the space of three inductors and the electrode size of the capacitor are carefully optimized and interconnected, since the proposed balun is the most sensitive to their component values. And also, the symmetric structure should be kept. The optimally designed LC balun has a size of 2mm×3.5mm×0.66mm (height).

2.2 Simulation Results

The proposed inductive coupled LC baluns have been simulated and characterized with 50Ω termination. The simulated frequencies are ranged from 0.1GHz to 7 GHz for commercial RF applications.

Figures 3 and 4 show 3D EM simulated results of the inductive coupled LC balun. As shown in Figures 3 and 4, it has wide bandwidth, phase imbalance, and magnitude imbalance characteristics. The simulated insertion and return losses are approximately −1.2 dB and −10dB at the operating frequency band, respectively. The simulated amplitude and phase difference are within 0.5 dB and 1 degree, respectively.

3. Conclusion

An inductive coupled LC balun has been optimally designed and simulated for embedding into an organic packaging substrate for low cost multiband wireless system applications. The designed balun consists of two asynchronously tuned resonators that are coupled magnetically which have been used for bandpass filter applications. It has bandpass characteristics and DC block. For reducing a size of the embedded capacitor, high dielectric film has been applied into the multi-layered organic packaging substrate. The designed balun has excellent performance characteristics and small size/volume.

4. Acknowledgment

This research was partially supported by the University Information Technology Research Center (ITRC) of the Korea Ministry of Information & Communication and Intelligent RF Engineering Research Center (ERC) of Korea Ministry of Science and Technology. The authors are grateful to MiNDaP group members for their technical supports. Mr. S.K. Yoon and Mr. Y.J. Ko of DaeDuck Electronics Co. are also acknowledged for their fabrication supports.

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