저가형 RF SOP 응용을 위한 임베디드 인덕터에 관한 연구

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PCB Embedded Spiral Inductors for low cost RF SOP Applications

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Abstract - In this paper, embedded spiral inductors are investigated into the PCB substrate for low cost RF SOP applications. The spiral inductors designed with geometrical variations were simulated, fabricated, measured, and characterized by using 3D EM simulator, 8 layered PCB standard process and HP 8510B network analyzer for verifying their applicability. The fabricated embedded spiral inductor has inductance of 9.4 nH at 800MHz, maximum quality factor of 64.8 at 1.09GHz and self resonant frequency of 3.93GHz, respectively. As the measured inductances and quality factors are well matched with simulated ones. PCB embedded spiral inductors are promising for advanced electronic systems with various functionality, low cost, small size and volume.

1. Introduction

Recent developments of wireless and mobile systems are extending information and communications markets. These markets require advanced electronic systems with small volume, low profile, light weight, low cost, excellent performance, and multi-functionality. SOP (System on a Package) is considered as one of the most challenged and exciting research areas for realizing the advanced electronic systems. EPC (Embedded Passive Components) is the most attractive research area in SOP technologies, because the number of the passive components and IC chips is steadily increasing as the advanced electronic systems towards for higher and multi functionality [1]. In particular, the inductor is very important among the passive components because it's the biggest among singular passive components. Several studies about the embedded inductors have been performed for RF and microwave SOP (System on a Package) [2-3]. LTCC (Low Temperature Co-fired Ceramic) has been widely studied, but it requires high temperature process that causes material shrinkage. Thus, it prevents the product reliability and drops the component yield. It is also limited to large area manufacturing. In this paper, the embedded inductors are investigated into the PCB (Printed Circuit Board) for low cost RF SOP applications. Embedded spiral inductors are designed, fabricated, and characterized for verifying their applicability by using 3D EM simulator.

2. Design and Fabrication

Figure 1 shows a schematic drawing of proposed PCB embedded spiral inductor. It is simulated by using 3D EM simulator and calculated by using semi-numerical theory for finding an optimal geometry [4]. Two different spiral inductors are designed with a planar and a stacked geometry. The planar inductors are designed with a single winding and two windings on 1st layer of PCB, while the stacked one is designed with two windings, a single winding on 1st and 3rd layers. These inductors are designed with the width of 100μm, spacing of 80μm, and thickness of 30μm of the conductor lines which standard PCB technology allows commonly. But the core sizeis varied for finding optimized geometry. The single turn wounded planar inductors have the core sizes ranged from 500 x 500μm^2 up to 2000 x 2000μm^2, while two turn inductors are ranged from 500 x 500μm^2 up to 1200 x 1200μm^2. And the two-turn stacked inductors have the core sizes ranged from 800 x 800μm^2 up to 1300 x 1300μm^2. Figure 2 shows a cross-sectional view of 8 layered PCB standard process for fabricating proposed embedded passive components.

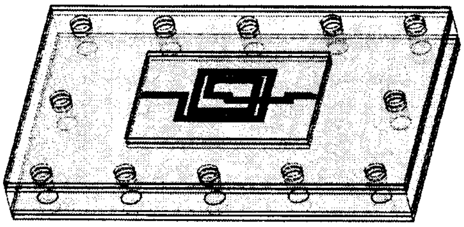

Figure 1. Schematic drawing of proposed PCB embedded 2-turn planar inductor.

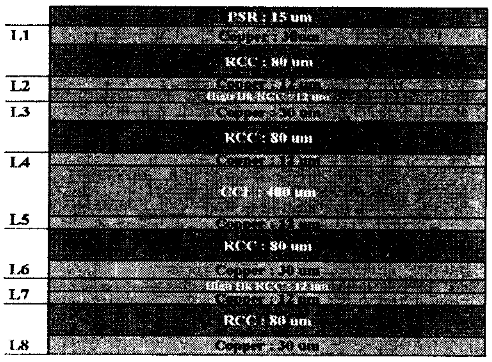

Figure 2. Cross-sectional view of 8 layer PCB standard processes to fabricate the embedded passive components.

The embedded inductors are fabricated on 1st through 3rd layer of PCB. As shown in Figure 2, the utilized 8 layered PCB is comprised of a resin coated copper (1st and 8th layer), high DK resin coated copper (2nd and 7th layer), resin coated copper (3rd and 6th layer), and copper clad laminate (4th and 8th layer). After fabrication of these embedded passive components, the PSR (Photo-imageable Solder Resist) was coated and patterned on top of the components. The GSG (Ground-Signal-Ground) test pads are finally formed and via-interconnected with the previously formed input / output ports and ground plane on the 1st layer. Figure 3 (a) and (b) show the fabricated PCB embedded planar and stacked spiral inductor for low cost RF SOP applications.

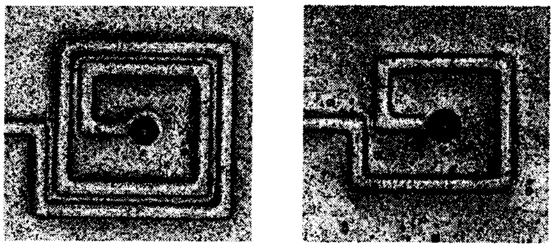
(a) (b)

Figure 3. Photomicrographs of the fabricated PCB embedded 2-turn planar inductor (a) and 2-turn stacked inductor (b) for RF SOP applications.

3. Experimental Results and Discussions

The fabricated PCB embedded passive components have been measured and characterized by using an HP 8510B network analyzer and PICOPROBE coplanar ground-signal-ground (GSG) probes with 250μm pitch size. The measured frequencies are ranged from 0.1GHz to 10GHz for mobile and wireless system applications. The parasitic capacitance degrades the quality factor because it partially cancels the actual inductance, and therefore reduces the energy storage capability of the inductor. The substrate capacitance depends on the dielectric constant of the substrate and the number of turns. The substrate capacitance is reduced by increasing the height from the ground plane [5]. To increase the height from the ground plane, the ground plane formed on 2nd through 4th layers underneath of the inductor was partially removed. Figure 4 shows the measured values of the inductance and quality factor for two turn planar spiral inductors with different core sizes. The spiral inductor with the core size of 900 x 900μm^2 has inductance of 9.4nH at 800MHz, maximum quality factor of 64.8 at 1.09GHz, and self resonant frequency of 3.93GHz, respectively. As the core size increases, the quality factor at high frequency and self resonant frequency decreases due to increased series resistance and substrate parasitics. Figure 5 shows the measured values of the inductance and quality factor for the planar spiral inductor with the same inductance and the different windings. The single turn and two-turn planar inductors with the same inductance of 6.4nH have maximum quality factor of 61.3 at 1.39GHz and 62.1 at 1.59GHz, respectively. Figure 6 shows the measured values of the two-turn planar and two-turn stacked spiral inductors with the same inductance of 8.4nH. The two-turn planar inductor has higher maximum quality factor, while the size of the stacked inductor is considerably reduced compared with the planar inductor. Figure 7 shows comparison of the measured and simulated performance characteristics of two-turn planar inductor with the core size of 900 x 900μm^2. As shown in Figure 7, the measured performance characteristics are well matched with simulated ones.

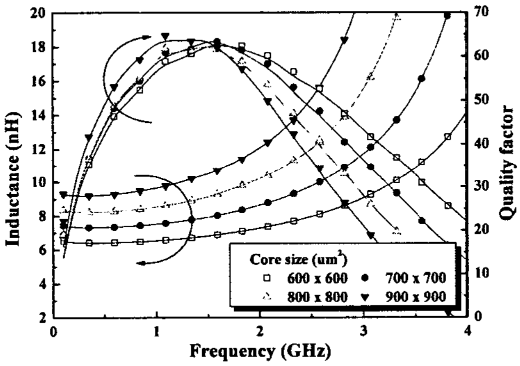

Figure 4. Comparison of inductance and quality factor of the fabricated PCB embedded 2-turn planar inductors as a function of core size.

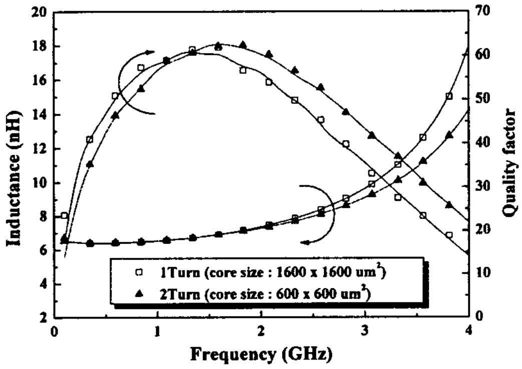

Figure 5. Comparison of quality factor of the fabricated PCB embedded planar inductors with same inductance and different windings.

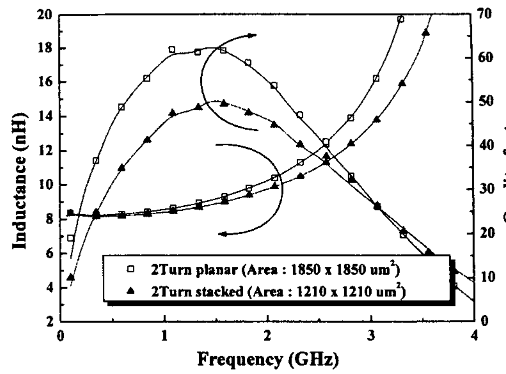

Figure 6. Comparison of quality factor of the fabricated PCB embedded spiral inductors with same inductance and different geometry.

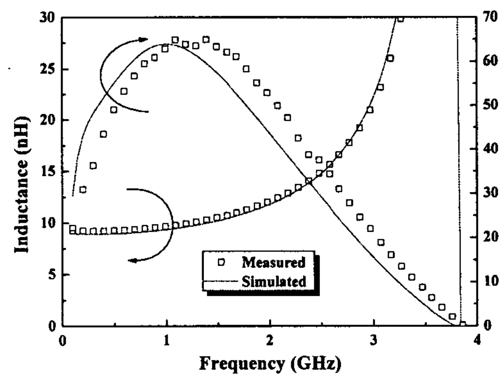

Figure 7.Comparison of the measured and simulated performance characteristics of the fabricated PCB embedded 2-turn planar inductor with core size of 900 x 900□m^2.

4. Conclusions

The different PCB embedded spiral inductors designed, fabricated, and characterized by using 3D EM simulator and 8 layered PCB standard processes. The fabricated PCB embedded inductors have excellent performance characteristics compared with LTCC ones. As the measured performance characteristics of the fabricated embedded inductors are well matched with the simulated ones, 3D EM simulation is confirmed as a promising method to design the PCB embedded spiral inductors for RF SOP applications. These embedded inductors are promising for developing the advanced electronic systems with various functionalities, lower cost, lower profile, smaller size and volume.

References

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