적층 유기기판 내에 내장된 소형 LC 다이플렉서의 설계 및 제작

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Design and Fabrication of Miniaturized LC Diplexer Embedded into Organic Substrate

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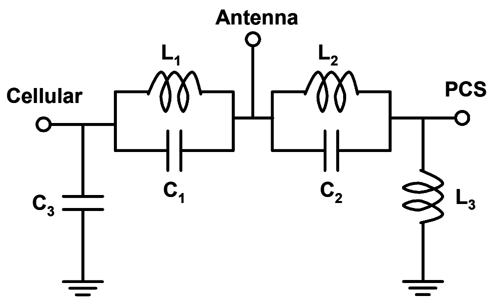
Abstract - In this paper, fully embedded and miniaturized diplexer has been designed, fabricated, and characterized for dual-band/mode CDMA handset applications. The size of the embedded diplexer is significantly reduced by embedding high Q circular spiral inductors and high DK MIM capacitors into low cost organic package substrate. The fabricated diplexer has insertion losses and isolations of -0.5 and -23dB at 824-894MHz and -0.7 and -22dB at 1850-1990MHz, respectively. Its size is 3.9mm x 3.9mm x 0.77mm (height). The fabricated diplexer is the smallest one which is fully embedded into low cost organic package substrate.

1. Introduction

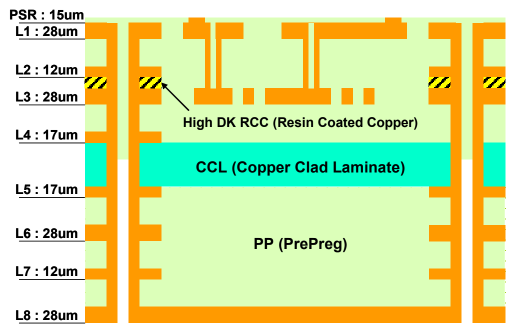
As mobile communication markets are demanding advanced electronic systems with small volume, low profile, light weight, low cost, excellent performance, and multi-functionality, EPD (Embedded Passive Devices) is being considered as one of the most crucial research areas for realizing these advanced electronic systems. In particular, the EPD is being actively researched in handset companies, because the number of the passive components and IC chips is steadily increasing in order to obtain higher and multi-functionality [1]. LTCC (Low Temperature Co-fired Ceramic) technology has been widely used to fabricate these embedded passive devices due to its high integration density [2-3]. However, the ceramic will shrink during the firing process at the high temperature, which might lead to the limitation of the product reliability and the component yield. It is also limited to large area manufacturing. Therefore, several studies on diplexers on low cost organic substrate, which are easy to manufacture in large area and to integrate with other printed RF circuits, have been performed. However, since these diplexers are much larger than the LTCC diplexers, they are limited to apply directly for advanced handsets [4-5]. In this paper, fully embedded diplexer is investigated into organic package substrate for small size and low cost FEM (Front End Module) for dual-mode/band system CDMA (Cellular/PCS) handset applications. The size of the embedded diplexer is significantly reduced by using fully embedded high Q circular spiral inductors and high DK MIM capacitors. The proposed diplexer is optimally designed for fabrication by using a circuit simulator and 3D-EM simulator.

2. Design and fabrication

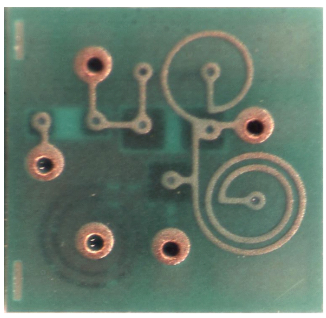
Fig. 1 shows equivalent circuit model of proposed diplexer to be embedded into organic package substrate for dual-mode/band CDMA (Cellular/PCS) handset applications. The proposed diplexer is comprised of modified second-order Chebyshev low-pass and high-pass filters, which are connected in parallel. The low-pass filter has a parallel LC resonator that resonates at the cutoff frequency of the high-pass filter, and vice versa. The reactance values of the proposed diplexer are obtained by using a lumped-element diplexer circuit topology [2]. As shown in Fig. 1, the proposed diplexer is comprised of three high Q inductors and three MIM capacitors. The embedded spiral inductors are designed with circular geometry to achieve higher quality factor and to reduce the diplexer area.



<Fig. 1> Schematic drawing of proposed diplexer embedded into organic package substrate.



<Fig. 2> A cross-sectional view of 8-layered organic package substrate to fabricate embedded diplexer with high Q circular spiral inductors and high DK MIM capacitors.



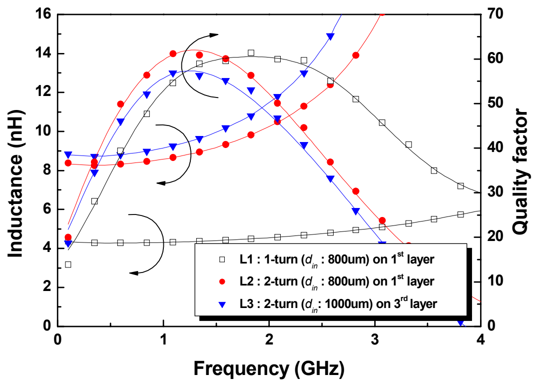
<Fig. 3> Photomicrograph of fabricated diplexer embedded into organic package substrate for dual-mode CDMA (Cellular/PCS) handset.

The center frequency and bandwidth of the diplexer is designed and optimized by varying the inner diameters of the high Q embedded circular spiral inductors. The embedded capacitors are designed with

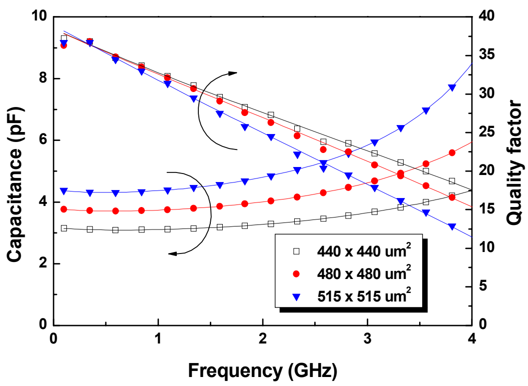
MIM geometry and high relative dielectric constant of 30 to reduce the diplexer area. The embedded MIM capacitors have capacitance of 1.5pF, 2pF and 4.6pF. The capacitors with capacitance of 1.5pF and 2pF are designed with series capacitor form with capacitance of 3pF and 4pF because of electrode area limited by fabrication tolerance. Fig. 2 shows a cross-sectional view of 8-layered organic package substrate to fabricate high Q inductors and MIM capacitors for embedded diplexer. The high Q inductors with circular spiral geometry are fully embedded into the 1st layer and 3rd layer of 8-layered organic package substrate. The embedded MIM capacitors into the 2nd layer are fabricated with the high dielectric composite film which is comprised of $BaTiO_3$ powder and epoxy resin. Fig. 3 shows photomicrograph of fabricated diplexer embedded into organic package substrate.

3. Experimental results and discussion

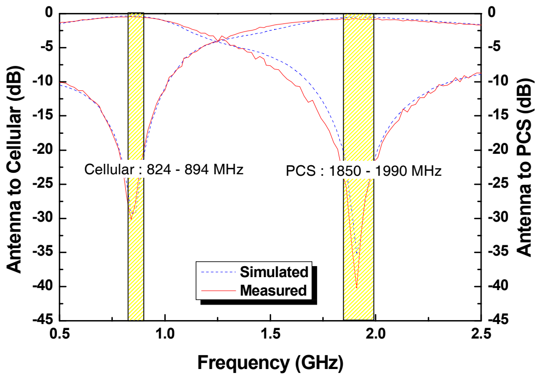
The fabricated embedded spiral inductors and MIM capacitors have been measured by using an HP8510B network analyzer and PICOPROBE coplanar ground-signal-ground (GSG) probes with 250um pitch size. The fabricated embedded diplexer is measured with an HP8510B network analyzer after mounting on a PCB test jig. Fig. 4 shows comparison of inductance and quality factor of circular spiral inductors with different windings and inner diameter (*din*). The quality factors of these embedded circular spiral inductors are ranged from 60 to 50 at the frequencies ranged from 1 to 2GHz. Fig.5 shows the comparison of capacitance and quality factor of the high DK MIM capacitors. The measured embedded MIM capacitors have the quality factors ranged from 35 to 25 at the frequency ranged from 1 to 2GHz.



<Fig. 4> Comparison of inductance and quality factor of circular spiral inductors embedded into the 1st layer and 3rd layer of 8-layered organic package substrate with different windings and inner diameter (*din*).



<Fig. 5> Comparison of capacitance and quality factor of the MIM capacitor embedded into the 2nd layer and 3rd layers with different top electrode area.



<Fig. 6> Comparison of simulated and measured performance characteristics of fully embedded diplexer with high Q embedded inductors and MIM capacitors.

Fig. 6 shows 3D-EM simulated and measured performance characteristics of embedded diplexer device. The fabricated diplexer has insertion losses and isolations of -0.5 and -23dB at 824-894MHz and -0.7 and -22dB at 1850-1990MHz, respectively. Its size is approximately 3.9mm x 3.9mm x 0.77mm. According to the measured results, insertion loss within the high-pass band is less than that of low-pass band, because of low quality factor of the MIM capacitor at high frequency. Capacitor with high relative dielectric constant has low quality factor due to the trade offs. The measured result shows good agreement with the simulated one.

4. Conclusion

Fully embedded diplexer comprised of several high Q inductors and MIM capacitors has been designed, fabricated, and characterized for small size and low cost FEM for advanced handset applications. The size of the diplexer has been dramatically reduced by using embedded circular spiral inductors and high DK MIM capacitors. It has excellent performance characteristics, which are well agreed with the simulated ones. The developed embedded passive circuit technology is widely applicable to advanced mixed signal electronic systems with low cost/profile, small size/volume, and multi-functionality.

Acknowledgments

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