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Design and Simulation of EMI Filter Based on LTCC Process Technology

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Keywords: component; formatting; style; styling; insert (Minimum 5 to 8 key words)

1. INTRODUCTION

With the development of science and technology, the frequent use of a large number of electronic components, has been resulting in electronic environmental pollution, electromagnetic interference (EMI), which is increasingly serious [1-3]. EMI filters for different frequency bands have been widely used in different application scenarios. On the other hand, the miniaturization and integration of electronic components puts higher requirements on the production process. LTCC process technology is one of the advanced three-dimensional packaging technologies, characterized by excellent high frequency characteristics, excel-lent transmission performance, high reliability and strong stability [4-7]. In this paper, the three-dimensional electromagnetic field simulation software HFSS is used to extract the values of the inductor and capacitor parameters. Based on the LTCC process, the third-order π-type Butterworth low-pass EMI filter is designed and simulated. Simultaneously, the S-parameters are analyzed, which provides a valuable reference for the development of related practical EMI filters.

2. DESIGN FOR EMI FILTER

2.1 Filter structure

The mainstream LC passive filter structure mainly includes T-type and π-type structures. This paper uses a 3rd-order π-type structure, shown in Figure 1. The Butterworth low-pass filter with a cut-off frequency of 310MHz is obtained by simulation software Advanced Design system (ADS). Table 1 shows the value of the filter's inductor and capacitor.

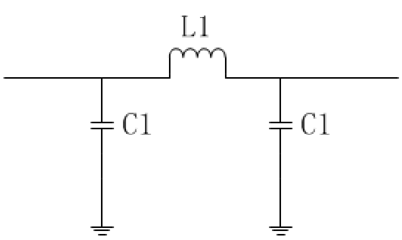

Figure 1 3rd-order π-type structure filter

Parameter	Value	Unit
L1	50.68629	nH
C1	10.13726	pF

Table1 The value of the inductor and capacitor

2.2 Design for inductor and capacitor

The capacitor is in the form of a Vertical-Interdigital-Capacitor (VIC), as shown in Figure 2. The vertical panel size of each layer is 0.8mm x 0.8mm. Figure 3 shows the vertical panel parameter values. Equation (1) gives the effective value of the capacitor by the conversion of the scattering parameters [8]:

$$L = \frac{-1}{2 \cdot \pi \cdot f \cdot im(Y11)} \quad (1)$$

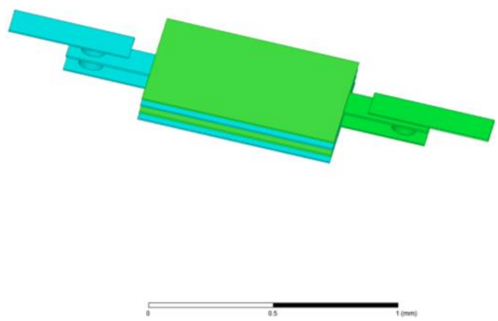

Figure 2 The VIC structure capacitor

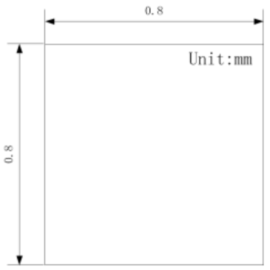

Figure 3 Vertical panel parameters of the capacitor

The inductor uses a spiral U-shaped structure as shown in Figure 4. Its long side is 0.8mm and the short side is 0.1mm. Figure 5 shows its U-shaped structural parameters. Equation (2) gives the effective value of the inductance by the conversion of the scattering parameters [9]:

$$C = \frac{-1}{2 \cdot \pi \cdot f \cdot im(Z11)} \quad (2)$$

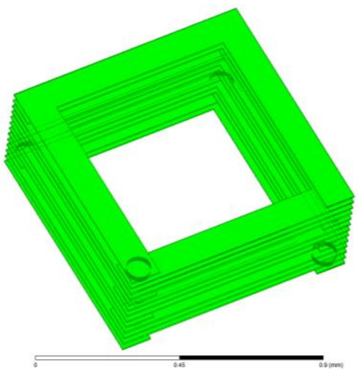

Figure 4 The U-shaped spiral inductor

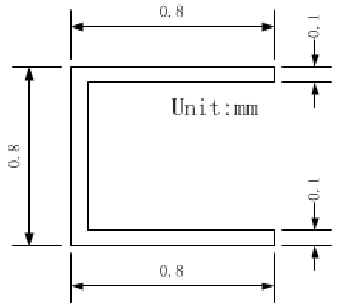

Figure 5 The U-shaped structural parameters

The filter designed in this paper uses the ULF900 ceramic material developed by Ferro and the dielectric constant is 90. The casting thickness is determined to be 0.024mm according to the LTCC process requirements. The conductive paste has a silver thickness of 0.006mm and the radius for via hole is 0.04mm. By continuously adjusting the number of inductor layers and the number of vertical panel layers of the capacitor, the simulation value is close to a predetermined value. Figure 6 gives the varying curve of the effective value of the inductor with frequency. At a frequency of about 310MHz, the equivalent inductor value is about 57.2nH. At a frequency of about 500MHz, the self- resonance happens and the inductor changes from inductive to capacitive. Figure 7 shows the varying curve of the effective value of the capacitor with frequency. At a frequency of about 310MHz, the equivalent capacitor value is about 12.01pF. At a frequency of about 1200MHz, the self- resonance happens and the inductor begins to change from capacitive to inductive.

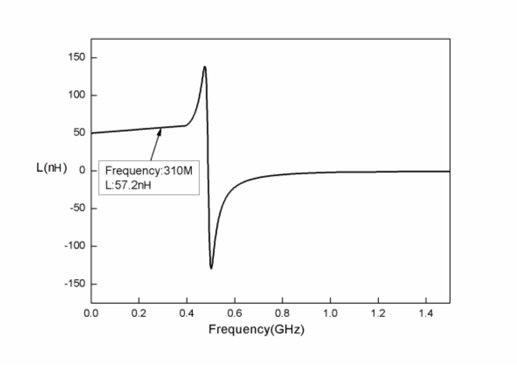

Figure 6 The varying curve of the effective value of the inductor with frequency++

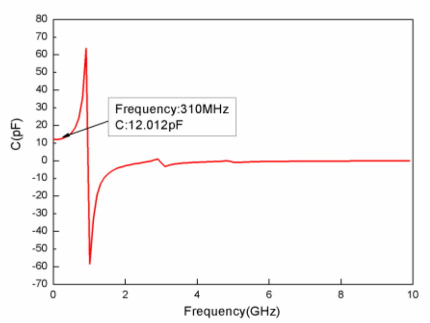

Figure 7 The varying curve of the effective value of the capacitor with frequency

3 SIMULATION FOR EMI FILTER

After simulating and analyzing the capacitor and inductor parameters, it is determined that the number of U-shaped spiral inductor layers is 14, and the number of vertical panel capacitor layers is 4 layers. A 3rd-order π-type Butterworth low-pass EMI filter is designed by the combination of LC inductors and capacitors. Figure 8 shows the physical model of the EMI filter, which size is 0.9mm x 0.9mm x 0.8mm. Figure 9 shows the varying curve of insertion loss and return loss with frequency for EMI filter. The cut-off frequency is about 340MHz with the insertion loss of 3.31dB, and the out-of-band rejection is greater than 40dB at frequency of about 1.1GHz. The filter cut-off frequency simulation value does not reach the predetermined value of 310 MHz, which may be due to the coupling effect between the capacitive and inductive components, or may be due to parasitic effects among the inductor, the capacitor and the ground.

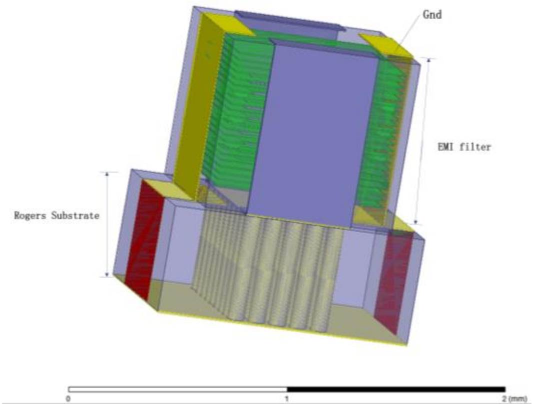

Figure 8 Physical model of the EMI filter

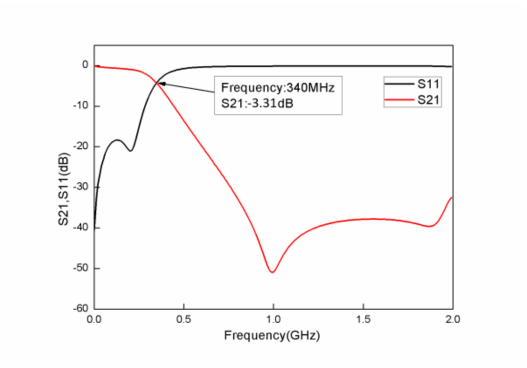

Figure 9 The varying curve of insertion loss and return loss with frequency for EMI filter

4. CONCLUSION

Through the 3D electromagnetic field simulation software HFSS, the design and simulation of the 3rd-order π-type Butterworth low-pass EMI filter based on LTCC technology shows that: 1 there are certain coupling effects and parasitic effects between the multilayer capacitor and the inductor. 2 A low-pass EMI filter with a cut-off frequency of 340MHz and an out-of-band rejection of more than 40dB at frequency of about 1.1GHz is successfully designed and simulated, which provides a valuable reference for the development of related devices.

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