The Design and Fabrication of RF Band Pass Filter by LTCC Technology

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Abstract

LTCC (Low Temperature Co-fired Ceramics) has been become the key technology of packaging for the integrated of RF passive components due to its higher performance of thermal sink, reliability and plays an important role in increasing higher frequency, decreasing the loss, minimize the volume, etc. This paper mainly focuses on the design and fabrication of RF band pass filter by LTCC technology. The filter model was established according to the capacitor coupled resonate band-pass filter's circuit structure and the connect type of embedded coupling capacitor was neatly designed to make it be linked between in port an out port, for two translations zeros using two stage resonator can be produced. After tuning up the distances between the strip line inductor and ground to adjust the inductance and quality Q, the circuit's whole performance could be improved. The band-pass filters with center frequency separated at 1.8GHz and 1.3GHz were fabricated using ULF140 material as the dielectrics to further validate the model and the samples were tested with high consistence with the simulated data.

Introduction

With the current explosive growth of communication technologies and a wide variety of applications being found for broadband and high frequency of electronic components, LTCC (Low Temperature Cofired Ceramics) with materials that possess special characteristics have been rapidly developed, due to its greater multifunctionality, higher performances, sub-miniaturization and excellent reliability. And it provides an easy way to embed passive components which can be mounted onto the surface of substrates and achieve circuit boards with the desired performances for high-density packaging. Therefore, LTCCs are regarded as a promising technology for the integration of components and substrates for high frequency applications.

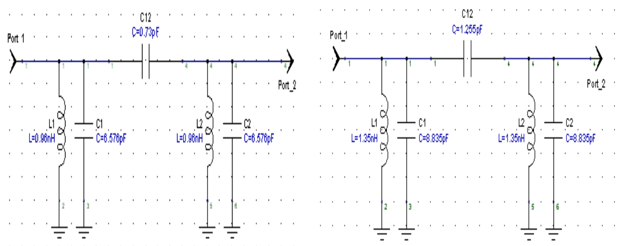
As one of the basic passive components, band-pass filters (BPF) play an import role in RF circuits to realize the function of signal band-passing and are extensively used to construct a variety of RF components such as power amplifier modules, transceiver modules and voltage controlled modules [1-6].

In this paper, the design method for BPFs with center frequency separated at 1.8GHz and 1.3GHz is developed based on the equivalent circuit. By employing the proposed design method, the multilayer chip BPF configuration can be made more compact and flexible. The designed chip-type BPF was realized by implementing the multilayer chip inductors and capacitors. Each lumped element was implemented using ceramic material and Ag metal layers. The dielectric constant and loss tangent was chosen to be 14 and 0.0015, respectively for 3D structure design of the chip BPF. The designed BPFs are fabricated by 33um thickness films and constructed by LTCC technology with excellent consistency between simulation and fabrication and merits of simple structures and low cost for wide applications.

Circuit and Stimulation

A. Circuit Model

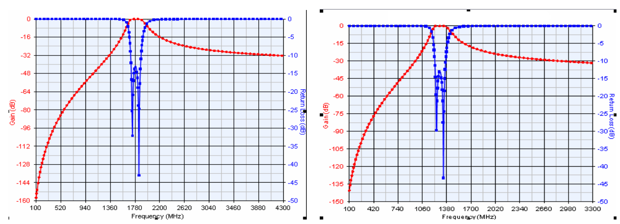
The BPFs were constructed by π type coupling capacitance circuit model through ADS designing software. The typical circuit and the parameters for BPFs were shown in Fig.1 which is composed of inductors and capacitors by circuit stimulation. Fig.2 depicts the stimulated results.



(a) (b)

Fig.1 The circuit model for band-pass filters (a) center frequency at 1.8GHz, (b) center frequency at 1.3GHz

From Fig.2, it can be seen that the attenuation over 25dB, the center frequency and the band-width about 200MHz could be achieved.



(a) (b)

Fig.2 The stimulated results of two kind of band-pass filters by ADS software (a) for center frequency at 1.8GHz, (b) for center frequency at 1.3GHz

However, the above results are only used to be referred, because accurate parameters of component model could not be extracted, due to the ADS designing software doesn't take the influences of parasitic parameters and the coupling effect into account during the fabricating process.

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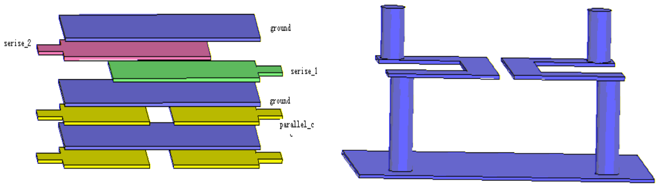
B. Component Implementation

The HFSS software has offered powerful functions to deal with the three-dimensional electro-magnetic fields' stimulation. According to actual conditions for the fabrication of filters, the equivalent circuit and an EM generated S-parameter database have been investigated with the collection of the electrical response by establishing the proper HFSS model for different available value.



(a) (b)

Fig.3 The physical prototype of capacitors (a) and the inductors with via-hole (b)

The structures of the capacitors and the inductors embedded in the filters were adopted as shown in Fig.3. To adapt the size of packaging for LTCC chip electronic component, it demands compact routing structure, especially in the Z direction. Therefore, the capacitors were designed to embed between the two ground metals in order to insulate the influences of the outside circuit and overcome the parasitic coupling phenomenon in some degree. From Fig.3. (b), it can be seen that the structure of inductor was made of square spirals structure, which is benefiting for improving Q value. And the via-holes were connected to the capacitors and the ground respectively to construct LC circuit together with the capacitors and to form the shunt resonator units.

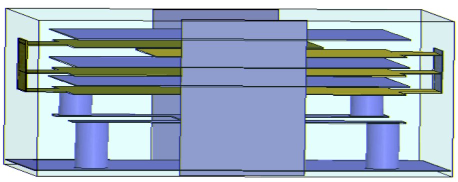
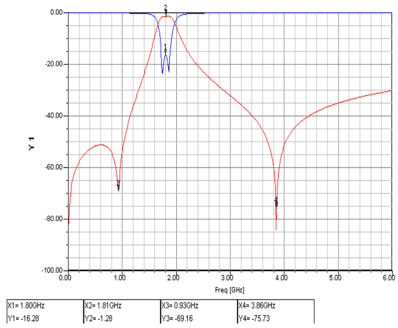
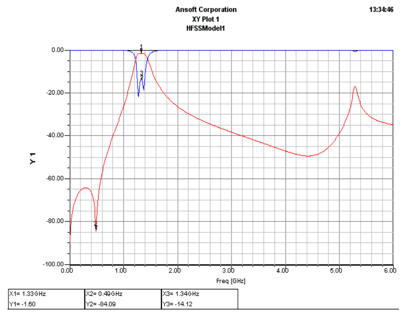


Fig.4 The physical prototype for band-pass filters

The physical prototype for BPFs was shown in Fig.4. The material was Ferro ULF140 with the dielectric constant of 14 and the thickness of each layer was 30um. After optimized, the characteristics of the filters simulated can be achieved and presented in Fig.5.



(a)



(b)

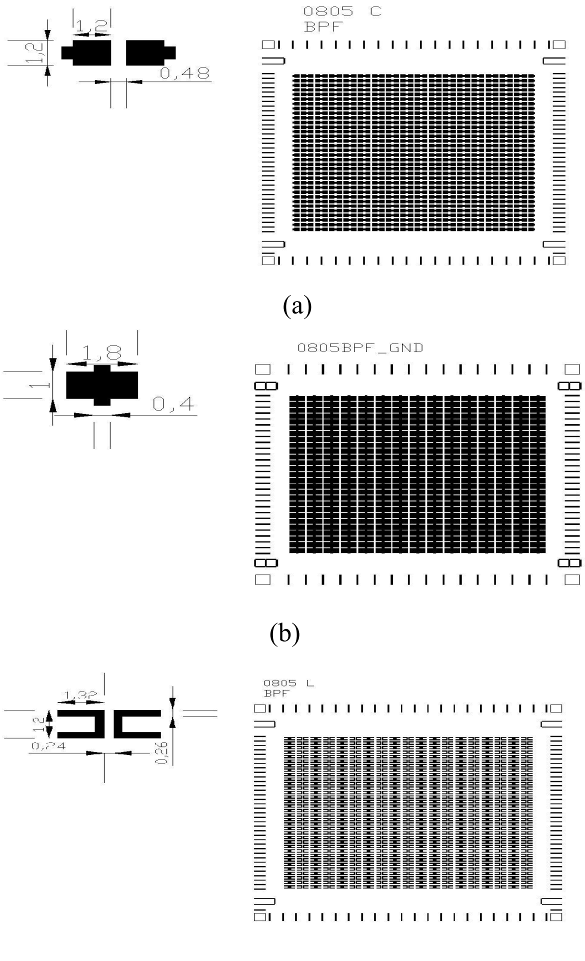
Fig.5 The stimulated results of two kind of band-pass filters by HFSS software (a) for center frequency at 1.8GHz, (b) for center frequency at 1.3GHz

From the response of three dimension configurations, the center frequency of the BPFs was 1.8GHz and 1.3GHz, the insertion losses were 1.3dB and 1.6dB respectively and the bandwidths were both about 200MHz. The difference from the circuit simulation by ADS software is that there are two translations zeros occurring, which improves the suppression performances for the filters. This can be explained by the theory of intercrossing coupling resonators and filters. So, the designing for the coupling capacitors at the input and output will produce translations zeros distributing outside of the pass-band which do good to improving the performances of filters.

Experimental

For LTCC process technology, the compatibility of system materials with respect to shrinkage, thermal expansion coefficient and chemical compatibility must be considered, different shrinkage rate of the fired specimens during co-firing make the materials distort, which cause deviation of the designed component. While designing silk screen, the pre-cofiring tape must be larger than designed model.

Fig.6. show the graphics of silk screen and relative sizes for one unit which will guarantee the good connection for each lays and formation of capacitors and inductors with the packaging size of 0805.



(c)

Fig.6. silk screen (a), (b), (c) for the fabrication of BPFs by LTCC technology with the packaging size of 0805

The conventional LTCC technology process was adopted to fabricate the laminated BPFs samples with the outline dimension of 2.0mm×1.2mm×0.9mm shown in Fig.7.

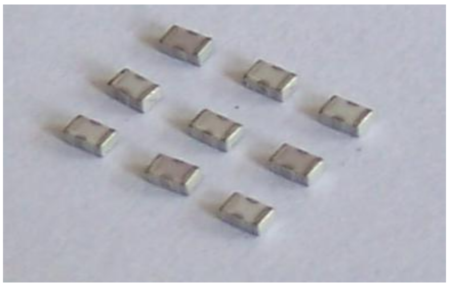
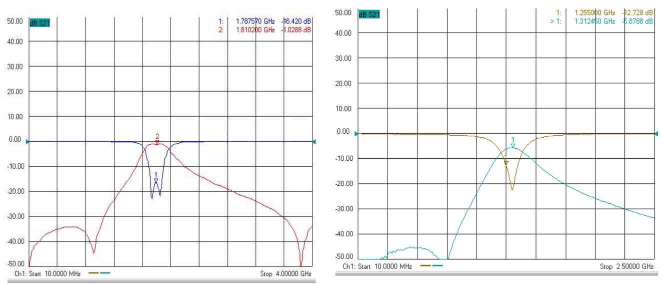


Fig.7. Experimental prototype for the samples

The measurements were carried on by Agilent 8722ES and the collected data was then calibrated to the desired reference plane by the thru-reflect line (TRL) technique through carefully designed calibration standards embedded in the same LTCC tie. The measured responses of the filters are shown Fig.8. From Fig.8, it can be clearly seen that the measured results agree with the simulated data basically. The center frequencies are 1.81 GHz and 1.31 GHz and the insertion loss in the center frequencies are -1.02dB and -5.88dB with reflection losses -16.4dB and -12.7dB respectively. There are two translations zeros had been observed at 0.91GHz and 3.84GHz for the BPF sample of 1.8GHz. Thus, a good coincidence between simulated and measured data is observed. The differences between the measurement and the stimulation are the center frequencies and the insertion losses are a little larger than the designed. It is believed that the deviation comes from the additional inductive and capacitive parasitic effects caused by the via. On the other hand, the process of LTCC technology also brings many errors which will introduce the manufacturing inaccuracy. Firstly, during the co-firing, the organic solvent in the silver conductor can not dispel all air bubbles, which cause the value of inductance and capacitance smaller and make the self-resonance frequency larger. Secondly, the effective value of the component can not be controlled accurately due to the difficulties of tiny manipulation problems including the printing and laminating.



(a) (b)

Fig.8. (a) The measurement result for 1.8GHz sample
(b) The measurement result for 1.3GHz sample

Conclusions

The structure analysis of LTCC-based passive components is reported for the design of a small multilayer chip BPFs and the filter model was established according to the capacitor coupled resonate band-pass filter's circuit. The BPFs fabricated by LTCC process has small size (2.0mm×1.2mm×0.9mm) using dielectric material ULF140. The center frequencies for BPFs samples are 1.81 GHz and 1.31 GHz, and the insertion loss in the center frequencies are -1.02dB and -5.88dB with reflection losses -16.4dB and -12.7dB respectively. The testing results are in a good agreement with the simulated data which will be helpful for the manufacture of passive components.

Acknowledgement

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