A Compact Band Pass Filter with Wide Stop-band in LGA Package by Low-temperature Co-fired Ceramic

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Abstract— A compact band pass filter with wide stop-band in land gird array (LGA) package was proposed in this paper. The proposed filter was designed to operate at 5.15 GHz–5.85 GHz for 802.11ac applications and implemented in low-temperature co-fired ceramic (LTCC) substrate. The proposed schematic introduces transmission zeros at the lower band to reject the unwanted frequency and extended wide stop-band at upper side with 30 dB rejection level from 9.55 GHz–18.45 GHz. The measured insertion loss is less than 1.0 dB at 5150–5850 MHz. The rejection level at lower side can be achieved 38 dB from measurement results. The measurement results and simulation are both shown and discussed.

1. INTRODUCTION

Recently, the rapid development of modern wireless and mobile communication system, the demand of filter is increasing. Especially, band-pass filter (BPF) plays an important role in communication systems. Low insertion loss, wide stop band, high selectivity, smaller size and lower cost are desirable in BPF design to improve the system performance. Many approaches have been proposed to have BPF with good stop band performance in [1–6]. In [1, 2], A microstrip bandpass with loaded stubs is proposed. In [3], a compact bandpass filter with quasi-lumped LC resonators on a defected ground structure was implemented on multilayer organic substrate. For device size reduction, many filters are realized on LTCC substrate [4, 5]. A second-order bandpass filter is proposed in [4]. This filter proposed an inductive-coupled and feedback path for a coupling capacitor and a grounding inductor to provide controllable transmission zeros. In [5], $2n$ transmission zeros can be generated to achieve wide-band suppression from cascading n filter cells. To have a minimized layout space in print circuit board (PCB), land grid array (LGA) package is utilized to reduce the land pad for component soldering in PCB.

In this letter, we propose a compact BPF with low insertion loss and wide upper stop-band which is implemented in LGA package by low temperature co-fired ceramic process. The proposed filter is using novel quasi-lumped LC resonator that includes coupled line which was consists of three transmission lines and vias, MIM capacitors and open stub to have better upper stopband performance. In addition, the proposed filter is implemented by LGA package to have small land pad size and reduce the effect of side termination.

2. FILTER DESIGN

The proposed circuit diagram is shown in Fig. 1. The proposed circuit is composed of three coupled line (CL1∼CL3), three coupling capacitors (C12/C23/C13), three capacitors to ground (C10/C20/C30), four small inductors (L1/L2/L10/L20) and two shunt open stub-lines (θ_1/ θ_2). The coupled line are each short to ground at the same end and opposite end are connected with MIM capacitors that used to reduce the physical length less than a quarter wavelength by loading capacitive loads. The open stub is used to produce the transmission zeros (TZ4, TZ5) to extend the stopband of high side. The transmission zero of the open-stub line can appear at the electric length of 90°. The smaller inductor (L10) that connected between the capacitors and ground provides opposite phase and creates the transmission zero at 10 GHz.

The transmission zero can be calculated as

$$f_{tz1} = f_1 \cdot \frac{\pi/2}{\theta_1} \tag{1}$$

$$f_{tz2} = f_2 \cdot \frac{\pi/2}{\theta_2} \tag{2}$$

The electric length of open stub are designed at 33° and 26°, respectively, to produce transmission zeros at 14.7 GHz and 18.1 GHz.

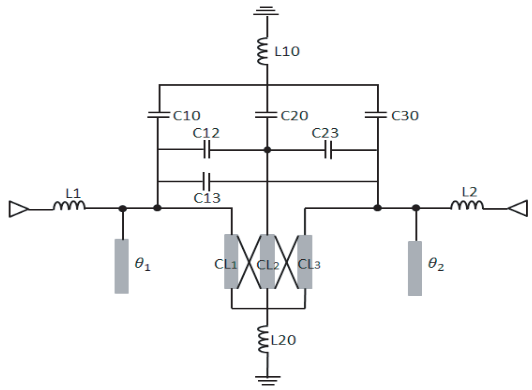

Figure 1: The equivalent circuit model for the proposed filter.

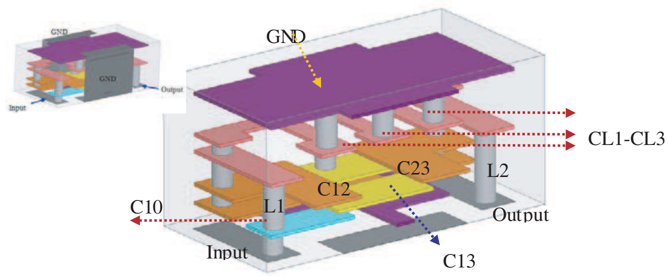

Figure 2: The 3D construction in HFSS.

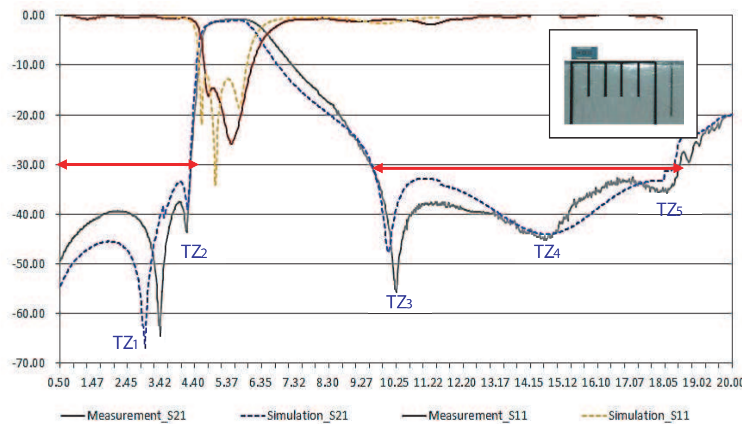

Figure 3: The simulation and measurement result.

This filter was realized in multilayer structure with LGA package which only need smaller footprint on print circuit board and avoid the coupling effect between side termination and inner metal layout. All the components of filter were embedded into the LTCC multi-layer substrate with a relative constant of 33, loss tangent of 0.001. The thickness of foil is 23 µm and the used conductor was silver with 10 µm thickness. The minimum line width and space between the lines were 100 µm and 150 µm, respectively. There are total 7 metal layers including 2 ground layers. The inductor elements and coupling line can be implemented by via and it can make the filter to have compact size. The 3D design for the proposed filter is to arrange the shielding ground on the top layer and it avoids the performance of filter to be effected by external environment, especially on SiP module application due to height limitation. The 3D structure of proposed filter and the corresponding three-dimensional structure of the component of the circuit model are also given in Fig. 2.

The overall size of band pass filter is 1.6 mm $(L) \times 0.8$ mm $(W) \times 0.58$ mm (H) which has compact size. The simulated response was shown in Fig. 3. The simulation insertion losses at 5.15 GHz and 5.85 GHz are 1.1 dB and 1.2 dB, respectively. It also shows that the central frequency is 5.5 GHz with 3 dB fractional bandwidth of 28.3%. The rejection band with 30 dB attenuation covers from 9.5 GHz to 181 GHz to have wide stopband. The proposed filter also has good attenuation at 500 MHz -4 GHz to reject the unwanted frequency band at low side.

3. MEASUREMENT RESULTS

The proposed filter is fabricated by LTCC process and its photograph is shown in Fig. 3. An Agilent E5071C Network Analyzer is used to measure the performance, and the frequency response for the simulated and measured magnituted of S_{21} and S_{11} of the proposed filter is shown in Fig. 3. From the measurement result, the insertion loss could be smaller than 1.05 dB between 5.15 GHz and 5.85 GHz. There are five transmission zeros. Two transmission zeros are located at 3.45 GHz and 4.4 GHz at lower side of the proposed bandpass filter. The other transmission zeros are locate at 10.25 GHz, 14.57 GHz and 18.10 GHz resultsing in wide upper stopband with 30 dB attenuation level. The electrical characteristics and dimension comparison are shown in Tables 1 and 2.

Table 1: The comparison for the electrical performance.

	Central frequency	Fractional bandwidth	Insertion Loss	Transmission zeros	Upper stopband
[1]	6.75 GHz	45.3%	-	3.59/8.5 GHz	20 dB up to $2.47f_0$
[2]	2.4 GHz	10.2 %	1.28 dB	1.6/2.6 GHz	20 dB up to $2f_0$
[3]	960 MHz	5%	4.0 dB	1.8 GHz	30 dB up to $5f_0$
[4]	2.45 GHz	4.08 %	1.5 dB	1.07/3.30/5.03 GHz	26.5 dB up to $2f_0$
[5]	2.45 GHz	4.1 %	1.5 dB	1.64/1.88/4.36/5.32 GHz	20 dB up to $2.2f_0$
[6]	2.35 GHz	6.54 %	2.11 dB	4.19/7.26 GHz	20 dB up to $4.5f_0$
This Work	5.5 GHz	31.56%	1.03 dB	3.38/4.16/10.25/ 14.57/18.10 GHz	20 dB up to $3.4f_0$

Table 2: The comparison for the physical characteristics.

	Substrate	Loss tangent	Dielectric Constant	Size
[1]	Duriod 5880	0.0009	2.2	$0.600\lambda g \times 0.37\lambda g$
[2]	F4B	0.001	2.45	$0.260\lambda g \times 0.260\lambda g$
[3]	LCP	0.002	2.9	$0.03\lambda g \times 0.13\lambda g$
[4]	Ceramic	0.003	7.8	$0.093\lambda g \times 0.043\lambda g$
[5]	Ceramic	0.0043	7.8	$0.12\lambda g \times 0.089\lambda g$
[6]	RT/5880	0.0009	2.2	$0.18\lambda g \times 0.26\lambda g$
This work	Ceramic	0.0045	7.5	$0.065\lambda g \times 0.32\lambda g$

4. CONCLUSION

The bandpass filter with LGA package is proposed in this study. The bandpass filter achieves bandwidth of 33.16% for passband and it reveals low insertion loss. In addition, multiple transmission zeros, good attenuation at upper stopband and compact chip size also demonstrate in our study. Specially, the measured result of the fabricated filter exhibits a very wide stopband up to 3.4 with a typically harmonic suppression more than 20 dB.

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