Print Parallel Coupling Wideband Filters on Al_2O_3 Ceramic Substrate

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Introduction

Micro-strip filters have found wide applications in microwave circuits and systems, and this is particularly driven by rapidly growing wireless communications. Recently, broad bandwidth devices are more important demand in the wireless communication applications [1, 2]. For the parallel-coupled microstrip line technology, increasing the coupling coefficient of resonators will increase the bandwidth and decrease the insertion loss, the most direct method of increasing coupling coefficient is to reduce the interval of resonators, but this will bring about hard fabrication. General speaking, reducing the interval of resonators is not the only method for the increasing the coupling coefficient [1, 2]. Increasing the order of filters is another method, but that will increase insertion loss and size of the designed filter [3-5].

In this paper, Al_2O_3 ceramic (the dielectric constant ε_r is 9.8) is used as the substrate of 3-order parallel-coupled microstrip line filters, and the input and output of filters are two 50Ω microstrip line. In the past, the parallel coupling filters were fabricated on the FR4 substrate, and almost no parallel coupling wideband filters were fabricated on ceramic substrate. For that, we will fabricate the parallel coupling wideband filters on the ceramic substrates and find the influences of designed parameters, including the coupling length and coupling gap between the input/output microstrip lines and the parallel resonators. The influences of coupling length and coupling gap between the three order resonators are also considered in this study. As compared to FR4 substrate, the Al_2O_3 substrates have higher dielectric constant and the higher quality factor. For that, we will show that the wideband parallel-coupled filters can be designed in small size with wider intervals of resonators without decreasing the insertion loss and increasing the ripple in the passband.

Filter Design and Fabrication

The width of micro-strip line was decided by the thickness and dielectric constant of the substrate for the impedance matching of 50Ω. The configuration of designed microstrip resonator was shown in Figure 1, five lines with the same length and width were parallel at the upper layer and the ground plane was printed on the other side. The first and the fifth lines were used as the 50Ω input and output microstrip lines, and the second to fourth lines were used as the resonators to get the wideband filters. The structure parameters (displacement: A and B, interval: C and D) were changed to find the optimal characteristics of the designed filters. As the parallel microstrip lines structure shown in Figure 1, the parameters of A, B, C and D had the large influences on the coupling effects of designed filters. Too much coupling would enlarge the ripple in the passband and decrease the bandwidth; too less coupling would decrease the insertion loss in the passband and the value of out-band rejection. The parameters of resonators were first obtained using IE3D simulation tool, which took the effect of dielectric loss into account. After simulation, the designed filters under all parameters were fabricated and measured to compare the simulated results. The parameters of the designed filters were length=20 mm, width=1 mm, A= 0~1.0 mm, B=

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0~1.0 mm, C= 0.1~0.5 mm and D= 0.6~1.4 mm. Al_2O_3 ceramic (the quality factor was about 30000 at 10GHz, the thickness was 1 mm and the dielectric constant was 9.8) was used as the substrate of the designed filters. The mask was done according to the simulated patterns, and then the mask was used to print the Ag/Pd paste on the Al_2O_3 substrates by a screen printer. The printed filters are fired in an oven for 800^oC/30min. Finally, the characteristics were measured by an impedance analyzer (HP-8720).

Results and Discussion

For the designed wideband filers, the definitions of bandwidth (BW, the range of -3dB during the passband), the ripple and the minimum insertion loss of the passband (Min S_{21}), and the frequency (Z_L(f)) and dB (Z_L(dB)) of the left-transmission zero are defined in Figure 2, respectively. The variation of structure parameters (A, B, C, D) shown in Figure. 1 will influence the characteristics of designed filters and the details are discussed below. At first, Table I first compares the simulated and measured characteristics of the designed filters due to the variation of displacement parameter A, and the other parameters are set at B=0 mm, C=0.1 mm and D=1.0 mm.

As the displacement A increases from 0 mm to 1 mm, the simulated (measured) ripple decreases from 1.2 (1.22) dB to 0.8 (0.76) dB, the simulated (measured) Z_L(dB) increases from −56.06 (−58.43) dB to −63.79 (−64.88) dB, the simulated (measured) Z_L(f) is shifted from 3.58 (3.07) GHZ to 3.83 (3.38) GHZ, the Min S_{21} value decreases slightly, and the BW value slightly increases. As Figure 1 shows, the function of parameter A is used to adjust the coupling effect between input/output and resonator. For that the parameter A will have larger influence on the values of ripple, Z_L(f) and Z_L(dB). These results suggest that the increase of parameter A, the designed filters have the better characteristics because the Z_L(dB) and BW increase and the ripple decreases. These result also show that the values of Z_L(f) have the large difference between the simulated and measured results, and the other measured results are matched the simulated ones.

The simulated and measured characteristics due to the variation of parameter B are compared, while the other parameters are set at A=0.5 mm, C=0.1 mm and D=1.0 mm. As the displacement B increases 0 to 1mmm, the simulated (measured) ripple increases from 0.98 (0.967) dB to 1.22 (1.241) dB, the simulated (measured) Z_L(dB) increases -58.71 (-60.79) dB to -68.95 (-70.03) dB, the simulated (measured) Z_L(f) is shifted from 3.70 (3.25) GHZ to 4.00 (3.63) GHZ, and the simulated (measured) Min S_{21} value and BW value are almost unchanged. However, the Z_L(f) values also have the large difference between the simulated and measured results. While the variation of interval C is changed, the A, B and D are set at 0.5 mm, 0 mm and 1.0 mm, respectively. As interval C increases from 0.1mm to 0.5mm, the simulated (measured) Min S_{21} value and BW value are almost unchanged. And the simulated (measured) ripple critically increases from 0.99 (0.967) dB to 1.81 (1.859) dB. Theses results suggest the increase of the interval C will degenerate the characteristics of ripple in the passband.

The simulated and measured characteristics due to the variation of interval D are also compared in Table I, and the other parameters are A=0.5 mm, B=0 mm and C=0.1 mm, respectively. As parameter D increases 0.6 mm to 1 mm, the BW and the ripple decrease, and the Z_L(f) and Z_L (dB) values have no apparent change. According to the results of simulation and measurement in Table I, the optimal parameters of the designed filter are A=0.5 mm, B=0 mm, C=0.1 mm, and D=1.0 mm, as the fabricated filters shown Figure. 3. Figure. 4 shows the characteristics of fabricated filter under optimal parameters, the measured results of fabricated filter are much closed to the simulated one. For the fabricated filter, the simulated Min S_{21} and ripple are −0.44 dB and 0.98 dB, however, the measured Min S_{21} and ripple are –0.743dB and 0.967 dB, respectively. The differences between the measured and simulated results are smaller than 0.4 dB; The measured BW, (Z_L(f) and Z_L(dB) are 1.145 GHz, 3.25 GHz and –60.79 dB, respectively. It is acceptable for the application in microwave communication.

Conclusions

In this paper, low loss wideband 3 order parallel-coupled microstrip line filters are fabricated, and the influences of the designed parameters are well developed in this study. As the displacement parameter A increases, the insertion loss and ripple decrease and the bandwidth increases; As the displacement parameter B increases, the bandwidth decreases and the insertion loss and ripple increase. On the other word, for the purpose of low ripple and wideband, the best choice is to increase A and decrease B. For the interval parameters C and D, increasing of them will decrease bandwidth, for the reason of wideband, decrease the interval parameters (C and D) will be a good choice, however, the decrease of interval will also increase the coupling of each resonators. Due to the higher the dielectric constant and the high quality factor of the Al_2O_3 ceramic substrate, the wideband filters have the advantages of small size (about 25 mm × 6.2 mm), good insertion loss and the ripple characteristics in the passband, wide bandwidth and large left-transmission zero. From above results, the fabricated filters are suitable for the wideband microwave applications of WLAN system.

References

[1] J. T. Kuo and E. Shih, “Wideband bandpass filter design with three-line microstrip structures,” *IEE Proc-Microw. Antennas Propug.,* vol. 149, pp. 243-245, October/ December 2002.

[2] K. S. Chin, L.Y. Lin, and J. T. Kuo, “New formulas for synthesizing microstrip bandpass filters with relatively wide bandwidths,” *IEEE Microw. Wireless Compon. Lett.,* vol. 14, pp. 231-233, May 2004.

[3] B. S. Kim, J. W. Lee, and M. S. Song, “An implementation of harmonic-suppression Microstrip filters with periodic grooves,” *IEEE Microw. Wireless Compon. Lett.,* vol. 14, pp. 413-415, September 2004.

[4] W. M. Fathelbab and M. B. Steer, “Parallel-coupled line filters with enhanced stopband performances,” *IEEE Trans. Microw. Theory Tech.,* vol. 53, pp. 3774-3779, December 2005.

[5] K. S. Chin and J. T. Kuo, “Insertion loss function synthesis of maximally flat parallel-coupled line bandpass filters,” *IEEE Trans. Microw. Theory Tech.,* vol. 53, pp. 3161-3167, October 2005.

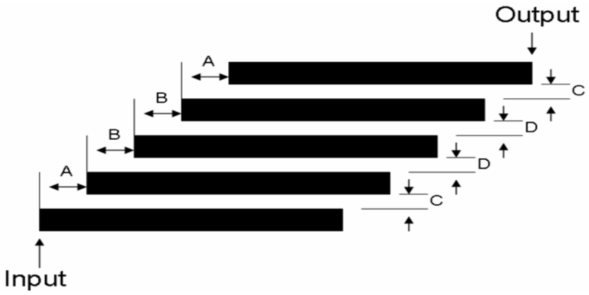

Figure 1. The layout of designed filter.

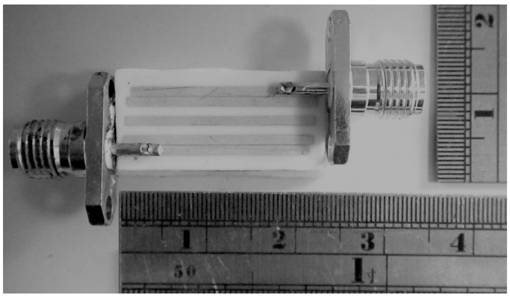

Figure 3. The photograph of proposed filter.

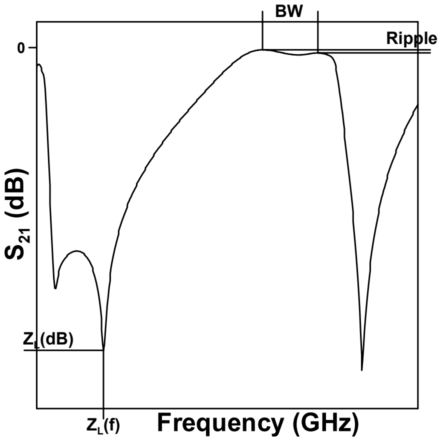

Figure 2. S_{21} frequency response.

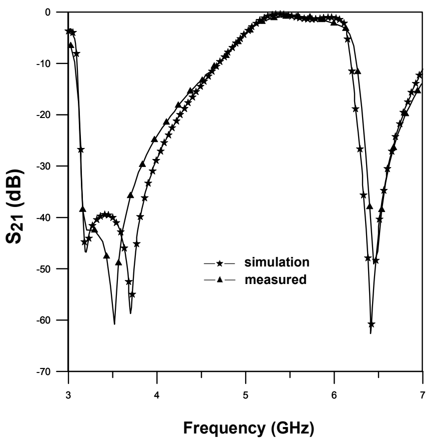

Figure 4. The simulated and fabricated characteristics of designed filter.

Table I: The simulated (S) and measured (M) results due to the variations of parameters A, B, C and D.

	A mm	S_{21} dB	Z_L dB	Z_L GHz	BW GHz	Ripple dB	**B mm**	S_{21} dB	Z_L dB	Z_L GHz	BW GHz	Ripple dB
S	**0**	-0.45	-56.1	3.58	1.09	1.2	**0**	-0.44	-58.71	3.7	1.1	0.98
M	**0**	-0.75	-58.4	3.07	1.13	1.22	**0**	-0.74	-60.79	3.25	1.15	0.97
S	**0.2**	-0.45	-57.0	3.63	1.09	1.12	**0.2**	-0.44	-59.8	3.76	1.1	1.07
M	**0.2**	-0.75	-59.6	3.1	1.12	1.10	**0.2**	-0.74	-61.98	3.33	1.14	1.06
S	**0.4**	-0.44	-57.7	3.68	1.1	1.03	**0.4**	-0.44	-61.17	3.81	1.09	1.14
M	**0.4**	-0.75	-60.1	3.16	1.15	1.02	**0.4**	-0.74	-63.16	3.41	1.13	1.15
S	**0.5**	-0.44	-58.7	3.7	1.1	0.98	**0.6**	-0.45	-64.53	3.87	1.09	1.18
M	**0.5**	-0.743	-60.8	3.25	1.15	0.97	**0.6**	-0.75	-66.47	3.49	1.13	1.17
S	**0.6**	-0.43	-59.3	3.73	1.1	0.94	**0.8**	-0.45	-67.11	3.94	1.08	1.21
M	**0.6**	-0.74	-61.3	3.29	1.15	0.94	**0.8**	-0.75	-68.12	3.56	1.13	1.22
S	**0.8**	-0.43	-61.2	3.77	1.1	0.86	**1.0**	-0.46	-68.95	4.0	1.07	1.22
M	**0.8**	-0.74	-62.5	3.33	1.15	0.87	**1.0**	-0.76	-70.03	3.63	1.13	1.24
	C mm	S_{21} dB	Z_L dB	Z_L GHz	BW GHz	Ripple dB	**D mm**	S_{21} dB	Z_L dB	Z_L GHz	BW GHz	Ripple dB
S	**0.1**	-0.43	-58.71	3.7	0.99	1.1	**0.6**	-0.38	-59.11	3.7	1.23	1.25
M	**0.1**	-0.74	-60.79	3.25	0.97	1.145	**0.6**	-0.71	-61.05	3.26	1.20	1.26
S	**0.2**	-0.43	-58.64	3.7	1.13	1.1	**0.8**	-0.4	-58.9	3.7	1.09	1.18
M	**0.2**	-0.75	-60.63	3.24	1.10	1.141	**0.8**	-0.74	-60.56	3.24	1.08	1.21
S	**0.3**	-0.44	-58.48	3.7	1.32	1.09	**1.0**	-0.44	-58.71	3.7	0.98	1.1
M	**0.3**	-0.75	-60.16	3.25	1.28	1.137	**1.0**	-0.74	-60.29	3.25	0.97	1.15
S	**0.4**	-0.45	-58.29	3.71	1.56	1.09	**1.2**	-0.47	-58.46	3.71	0.94	1.01
M	**0.4**	-0.75	-60.55	3.26	1.60	1.139	**1.2**	-0.74	-60.17	3.27	0.95	1.12
S	**0.5**	-0.48	-58.35	3.71	1.81	1.08	**1.4**	-0.51	-58.37	3.71	0.87	0.92
M	**0.5**	-0.75	-60.32	3.24	1.86	1.136	**1.4**	-0.75	-59.93	3.24	0.90	1.07