Design of an Ultra-compact Dual-band Bandpass Filter with CRLH Resonator

Hailin Cao, Member, IEEE, Mao Yi, Huan Chen, Jiujiu Liu, Jianshuo Liang and Wenbin Cai
Key Laboratory of Aerocraft Tracking, Telemetering & Command and Communication (Ministry of Education),Chongqing University, Chongqing ,400044,China

***Abstract* - An ultra-compact dual-band bandpass filter (BPF) with coupled novel composite-right/left-handed (CRLH) resonators is presented. The proposed CRLH resonator is constructed by a serial interdigital capacitor and a short-ended meander line, which have the advantages of small size and more flexible resonant frequency allocation. The proposed filter has been simulated, fabricated and measured. The dual-band BPF achieves the fractional bandwidth approximately 12.7% at the first center frequency 0.95 GHz and 9.2% at the second center frequency 3.12GHz, the return loss is greater than 10 dB in passband, with an ultra-compact size as small as 0.11λg×0.059λg, λg is the guided wavelength at the center frequency of the first passband.**

***Index Terms* —dual-band, bandpass filter (BPF), composite-right/left-handed (CRLH)Introduction**

I. INTRODUCTION

Recently, various dual-band BPFs have been extensively studied and developed to meet requirements to suppress unwanted spurious signals in modern multiband wireless communication systems [1].The most direct method to implement microstrip dual-band BPF is combing two sets of different resonators with common input and output [2]-[3]. However, these filters generally occupy a large area. On the other hand, dual-mode or multi-mode resonators have been reported to improve the performance of the dual-band bandpass filter with simple layout and compact size [4]-[9]. With the investigation on simple shape ring resonator, a tri-band dual-mode MMIC filter is stacked [4]. In [5], a compact dual-mode tri-band BPF is designed by a short-circuited stub-loaded stepped-impedance resonator (SIR). Different from traditional stepped-impedance resonators, stub-loaded structures can control resonant frequencies independently. In [6], a single quadruple-mode resonator (QMR) is proposed to design dual-mode dual-band BPFs. Single [7] or combined [8] multi-stub-loaded resonators with shorted stub are also proposed to buid dual-band BPFs.

The composite right/left handed (CRLH) transmission line, which exhibits backward (or left handed) wave propagation at low frequencies and forward (or right handed) wave propagation at high frequencies, is proposed and applied in recent years [9]. There has been an increasing interest on the design and fabrication of dual-band power splitters and dividers based on resonant-type (complementary) split-rings resonators (SRR) [10]-[11]. The nonresonant-type LHM, composed of the periodic series capacitors and shunt inductors, providing broad bandwidth and small loss in the left-handed (LH) passband, thus facilitate more applications such as leaky wave antenna [12].

In this paper, A dual-band BPF with two back to back coupled CRLH resonators is designed, simulated, and fabricated. It is learned from the measured data that the proposed filter based on such resonators exhibits ultra compact dimension and high selectivity. The dual-band BPF covers a fractional tuning range of 12.7% at the first center frequency 0.95 GHz and 9.2% at the second center frequency 3.12GHz, while maintaining good selectivity.

II. FILTER DESIGN CONSIDERATION

The geometric structure of the proposed dual-band BPF with two back to back coupled CRLH resonators is shown in Fig.1.

The filter was fabricated on a 0.762mm-thick Rogers 4350B substrate with a relative permittivity of 3.48 and dielectric loss tangent of 0.002. The overall size of the filter is 20.4mm × 11.2 mm excluding the feed line, all the appropriate dimensions are listed in Table 1.

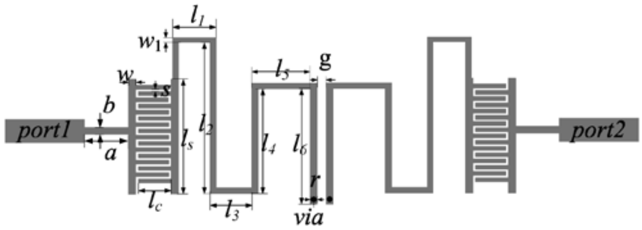

Fig. 1. Schematic of the proposed dual-band BPF

TABLE I
GOMETRIC DIMENSIONS OF PROPOSED FILTER
(UNIT: MILLIMETERS)

l_s	l_1	l_2	l_3	l_4	l_5	l_6
8.0	2.0	10.	2.0	7.0	3.3	9.0
l_c	w	w_1	s	a	b	g
1.33	0.6	0.5	0.1	2.4	0.5	0.2

The proposed BPF consists of two novel CRLH resonators, and a serial interdigital capacitor and a short-ended meander line. constitutes the resonator. A parametric study of the proposed resonator against the length of short-ended meander line l_2 and the interdigital capacitor dimension l_c, is shown in Fig.2(a)(b), respectively. And all the simulation is done on the full EM-Simulator (ANSYS

HFSS). By properly adjusting the parameters of the resonator, the desired frequency responses can be achieved.

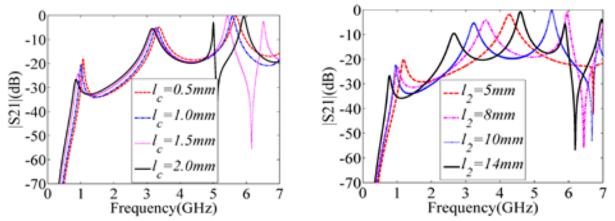

Fig. 2.(a) Simulated S_{21} of CRLH resonator with *lc*=0.5mm, *lc*=1.0mm, *lc*=1.5mm, *lc*=2.0mm. (b) Simulated S_{21} of CRLH resonator with l_2=5mm, l_2=8mm, l_2=10mm, l_2=14mm

III. Results and Discussion

To demonstrate the validity of the design strategies, one prototype of the proposed filter is fabricated and measured. The photograph of the proposed filter is shown in Fig.3(a)

Figure 3(b) plots the simulated and the measured S-parameters. The measured results from 10 MHz to 5GHz are extracted by Anritsu 37347C Vector Network Analyzer (VNA). It can be seen that the insertion loss is 1.2dB, at the first center frequency 0.95 GHz and 1.3dB at the second center frequency 3.12GHz, the return loss is greater than 10 dB in passband. The 3dB bandwidth of two passband is 0.13GHz\0.3 GHz, the fractional bandwidth is approximately 12.7%\9.2%. The discrepancies between the simulated and measured results, such as the increased insert loss and a few frequency offset, might be due to factors such as fabrication tolerances and material parameter uncertainty.

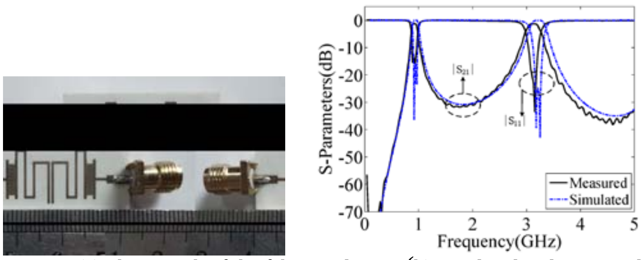

Fig. 3.(a) Photograph of the fabricated BPF, (b)Simulated and measured S-Parameters for the proposed BPF

TABLE II
PERFORMANCE COMPARISON WITH REPORTED BPF

Filter	1st/2nd passbands (GHz)	3-dB FBW(%)	Circuit size ($\lambda_g \times \lambda_g$)
[ref3]	2.4/5.2	16.4%/7.1%	0.11×0.11
[ref4]	1.96/5.58	57.1%/20.8%	0.40×0.05
[ref7]	2.4/3.5	2%/8.5%	0.33×0.15
[ref9]	1/1.2	4.6%/6.3%	0.24×0.27
This work	0.95/3.21	12.7%/9.2%	0.11×0.059

Table II shows the performance comparison of the proposed filter with the other reported dual-band BPFs. Comparing with the recently reported BPFs using SIR with stub-loaded structures or some modified techniques in [3],[5],[6],[8],[9], our device exhibits comparable return losses with slightly higher insertion loss. Bandwidth is comparable in the second band (or even superior as compared to [3]), but narrower in the first band. However, the proposed filter has an ultra compact size with $0.11\lambda_g \times 0.059\ \lambda_g$, λ_g is the guided wavelength at the center frequency of the first passband.

IV. Conclusion

An ultra-compact dual-band BPF with back to back coupled novel CRLH resonators is presented. The proposed filter has been simulated, fabricated and measured. Compared with former reported BPFs, the proposed filter has simpler geometry with an ultra-compact size as small as $0.11\lambda_g \times 0.059\lambda_g$. With the above attractive features, the proposed BPF based on the coupled CRLH cell is promising for the future microwave applications.

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