An Ultra-Compact VHF CRLH-Line Bandpass Filter Less Than (λ $_g$/19)^2 With a Broad Stopband

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***Abstract-* A VHF bandpass filter is designed to be extremely compact and working suitable for a lighter and high-fidelity T-DMB receiver. A super-small distributed element CRLH unit cell is devised based on the T-type equivalent circuit and the three blocks of the unit cell are cascaded by matching the neighboring impedances. Therefore, the overall footprint of the filter is less than (wavelength/19)x(wavelength/34), and the passband with low insertion- and return loss is obtained as demanded in the 180-MHz T-DMB service. Besides, this zeroth-order resonance filter shows an excellent performance of suppressing the spurious harmonics over a very broad stopband up to several GHz.**

I. INTRODUCTION

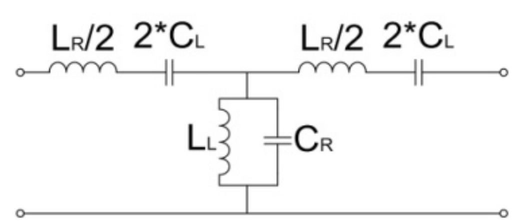
Since C. Caloz and T. Itoh introduced the concept of the composite right- and left-handed (CRLH) transmission-line(TL) and its lumped-element versions, it has been applied to improve RF hardware performances or reduce their physical sizes[1]. Negative resonance as well zeroth-order resonance is instrumental in size-reduction of microwave components and antennas [2]. Backward-waves can be used to increase the beam-scanning range of a leaky-wave antenna [3]. F. Martin et al formed pairs of slot rings coupled to capacitive gaps on the top surface of the microstrip filters [4]. While most of microwave CRLH-type passive components aim to work in the frequency above 1 GHz, a number of literatures present the RF component designs performing well in the UHF-band or even the VHF-region where it is usually challenging to reduce the physical sizes effectively and create the left-handed waves using the distributed CRLH elements [5-8].

In this paper, an enhanced compact VHF bandpass filter is designed. A spiral short-circuited stub is adopted for the CRLH unit-cell to increase the quality-factor of the shunt inductor and avoid the self-resonance caused harmonics, instead of the straight line. Along with this, an increased number of fingers with shorter lengths make the interdigital coupled-lines to minimize the inductive parasitics. These approaches will turn out appropriate to have better return loss result and harmonic-rejection over a broader stopband(above the 11th harmonic) compared to [6]. Notably, the overall area of the proposed filter is measured to be smaller than (wavelength/19)x(wavelength/34). In the passband of 180 MHz, the insertion loss is even lower than 2 dB with return loss of $|S_{11}| \leq -15$ dB.

II. INITIAL AND ADVANCED DESIGNS FOR THE PROPOSED FILTER

In the beginning, we design the unit cell to resonate at 180 MHz primarily, which will be unfolded to form the pass-band by coupling the adjacent cells in a later section. This physical resonator is first modelled by the equivalent circuit of the CRLH TL which is found in other literatures [1-8].

As was done in the aforementioned references, the series- and shunt LC pairs exist together in the equivalent circuit model, and this basic circuit is possibly expressed as a T-type as in Fig. 1a and a microstip line structure corresponding to this symmetric equivalent circuit expression of the CRLH-TL unit cell is suggested as in Fig. 1b. Compared to other works, a clear difference can be addressed with a view to circumventing a couple of the previous shortcomings. A spiral short-circuited stub is adopted for the CRLH unit-cell to increase the quality-factor of the shunt inductor to have a steeper skirt at the edges of the passband and avoid the self-resonance causing harmonics, instead of the long straight line. Besides, with this, an increased number of fingers with shorter lengths make the interdigital coupled-lines to minimize the inductive parasitics.



(a)

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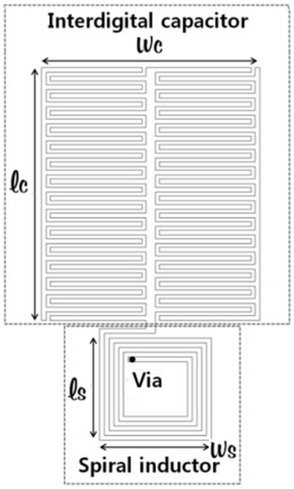

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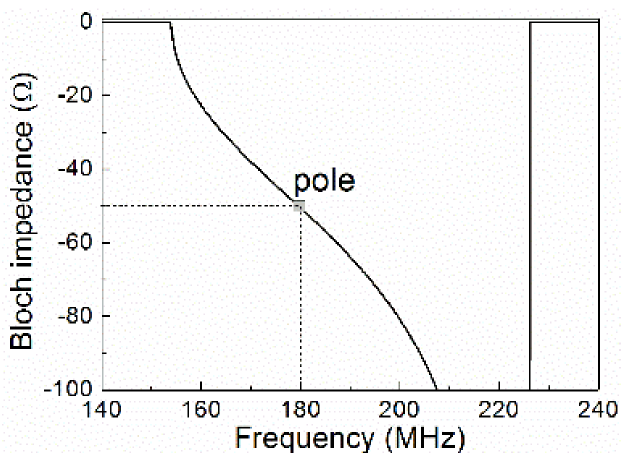
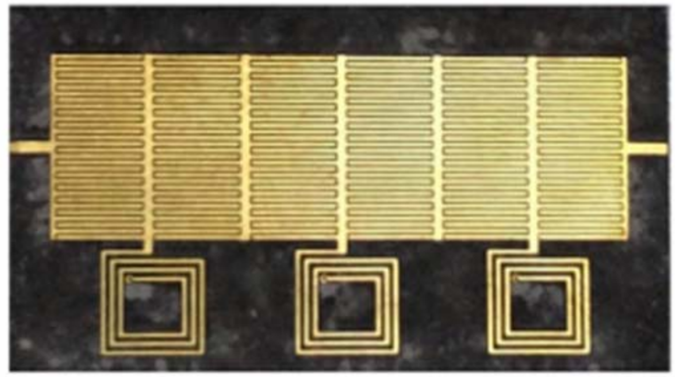


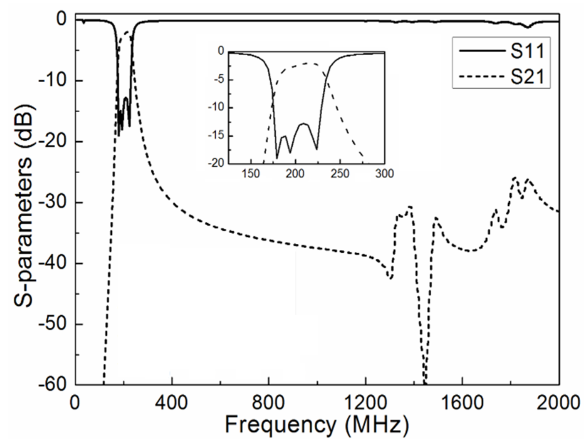
(c)

Figure.1. Equivalent circuit, geometry of the CRLH-TL unit-cell, and representative characteristic (l_s= 4.7, l_c= 10.36, w_s = 4.7, w_c = 9.16, unit: mm) (a) Equivalent circuit (b) Physical shape of the CRLH-TL unit cell (c) Bloch impedance.

Using the equations as in [5-7], the circuit elements are calculated for operating in T-DMB (174–216MHz) as 16.33 nH, 0 nH, 8.76 pF, 30.37 pF as L_L, L_R, C_L, C_R, respectively with Bloch impedance Z_B of 59 Ω. Fig. 1(c) implies the center frequency the passband is successfully achieved at 180 MHz with impedance matching as Z_B. This unit cell is replicated to its multiple cells and they are cascaded to form a bandpass filter.



(a)



(b)

Figure. 2. Geometry of the proposed VHF bandpass filter and its frequency response (a) Physical shape (b) S_{11} and S_{21}.

As the advanced step, the 3-cell structure is implemented and fabricated. The overall footprint of the filter is (λ_g/19)x(λ_g /34), where λ_g is the guided wavelength, which presents effective size-reduction. Seeing S_{11} and S_{21}, the passband is created in the VHF-band with a slight shift due to cheap fabrication. Low insertion-loss is obtained as below 2 dB. Furthermore, the spurious suppression is expanded up to several GHz with $|S_{21}|$< -30 dB.

III. Conclusion

A super-compact VHF-band filter was designed based on the modified CRLH unit-cells. Its passband, insertion- and return loss are acceptable. Also, a very broad stopband is noteworthy.

IV. Acknowledgement

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