Retraction

Retracted: Design of a Narrow Bandwidth Bandpass Filter Using Compact Spiral Resonator with Chirality

Active and Passive Electronic Components

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Active and Passive Electronic Components has retracted the article titled “Design of a Narrow Bandwidth Bandpass Filter Using Compact Spiral Resonator with Chirality” [1]. The article took the figures, the table, and most of the text from an unpublished article by Drs. Mohammad Reza Khawary, Seyed Mohammad Hashemi, Vahid Nayyeri, and Mohammad Soleimani previously submitted to IEEE Microwave and Wireless Components Letters in August 2015. The other journal confirmed the details of that earlier submission.

The first author does not agree with retraction and says their laboratory conducted this work, which was done by a former, unnamed student, and any similarity is a coincidence. We could not contact the other authors. The first author provided what they said were original simulation and measurement results, and said different software was used during filter design, simulation, optimization, and fabrication: CST for EM simulation, HFSS for resonant frequency extraction, ADS for circuit simulation, and AutoCAD for drawing the layout for fabrication; the filter was measured using R&S vector network analyzer.

References

[1] W. Li, Z. Tang, and X. Cao, “Design of a narrow bandwidth bandpass filter using compact spiral resonator with chirality,” Active and Passive Electronic Components, vol. 2016, Article ID 7074392, 6 pages, 2016.
Research Article

Design of a Narrow Bandwidth Bandpass Filter Using Compact Spiral Resonator with Chirality

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In this article, a compact narrow-bandpass filter with high selectivity and improved rejection level is presented. For miniaturization, a pair of double negative (DNG) cells consisting of quasi-planar chiral resonators are cascaded and electrically loaded to a microstrip transmission line; short ended stubs are introduced to expand upper rejection band. The structure is analyzed using equivalent circuit models and simulated based on EM simulation software. For validation, the proposed filter is fabricated and measured. The measured results are in good agreement with the simulated ones. By comparing to other filters in the references, it is shown that the proposed filter has the advantage of skirt selectivity and compact size, so it can be integrated more conveniently in modern wireless communication systems and microwave planar circuits.

1. Introduction

Design of very compact microwave devices compatible with printed circuit board and monolithic-microwave integrated-circuit fabrication technologies has gained great interest in the last decades. The split-ring resonators (SRRs) and their counterparts, complementary split-ring resonators (CSRRs), are key aspects that propose new design strategies to miniaturize planar microwave circuit [1]. It is demonstrated that, by combining two metal levels at both sides of a dielectric layer connected by vias with an appropriate topology, it is possible to design new resonators with a higher level of miniaturization [2]. These resonators which often exhibit chirality [3] can be used to synthesize left handed structures with neither severe degradation in the quality factor [2] nor causing electromagnetic compatibility (EMC) problems dealing with SRR and CSRR structures [3, 4].

Narrow-bandpass filters (NBPFs) with sharp selectivity and high rejection are increasingly demanded in modern microwave communications systems. In order to miniaturize such filters for circuit integration, many research works have been done. In [5], composite right/left-handed coplanar waveguide (CRLH-CPW) resonators are used to create a passband. But in general, the parasitic effects of CPW on the coupling gaps usually cannot be neglected. Therefore, the selectivity would be compromised. In [6], CSRRs have been loaded on the top side of the substrate, but a good deal of insertion loss of the passband is caused by the coupling and fringing capacitance brought by this structure. Also, unwanted spurious responses occur. In [7], multisection stepped-impedance resonators are cascaded to create a relative wide passband. However, the resonant mode cannot be easily controlled and the design process is comparatively complex. In [8], electromagnetic bandgap (EBG) is introduced on the ground plane of the filter. Better out-of-band rejection has been achieved and the design process can be more flexible. But in most cases, the loss of the in-band frequency response is inevitably increased by the rejection effect of EBG. Therefore, some performances must be balanced to make compromises. In [9], SRRs are coupled together to create a single passband. Since the structures of SRRs and CSRRs are quite the same, similar problems have
been encountered as that with CSRRs. Recently, other types of structures have been proposed to overcome the aforementioned disadvantages. In [10–17], composite right/left-handed (CRLH) metamaterial structure is demonstrated. CRLH resonators have positive, negative, and zeroth resonant modes based on the working condition. At zeroth resonant mode, the passband can achieve the highest selectivity with the lowest insertion loss due to the low conductor loss at this special resonant mode. In addition, CRLH resonators are often designed in the form of interdigital or spiral geometric structure, which makes the size more compact. In [18–25], defected ground structure (DGS) has been proposed. DGSs are etched at the bottom plane of the resonators and band-stop frequency responses are achieved. Since DGS is independent of the resonators on the upper layer, the design process can be much more flexible. Out-of-band rejection can be increased by the slow-wave effect of DGS. Moreover, DGS are perfectly compatible with CRLH structures. In order to further miniaturize the size of the microwave circuit, in [26], multilayered quasi-planar structure is proposed. Different electromagnetic structures are packed into different layers of the substrate through weak coupling. Thus, more compact size has been achieved without major influence on the performances of the device. Inspired by these previous literatures, in our work, a novel NBPF with good selectivity and higher level of miniaturization using quasi-planar chiral resonators is proposed. The corresponding equivalent circuit has been analyzed and the results of full-wave simulation and experimental measurement have been presented.

2. Filter Design

Figure 1(a) shows the topology of the double negative (DNG) cell conceptually proposed in [4], consisting of a microstrip line with series gaps and a quasi-planar chiral resonator, electrically loaded to the transmission line. As illustrated in Figure 1(a), this topology can be printed on the surfaces of a three-layer substrate. The circuit model of the cell and its transformed T-model are depicted in Figure 1(b) (the circuit model is clearly described in [4]). In [4] it was demonstrated that this resonator provides negative permittivity in a narrow band after its resonant frequency. On the other hand, series gaps ($G_p$) between transmission lines expose negative permeability before their plasma frequency. Thus, this subwave-length structure with appropriate topology supports backward-wave propagation in a narrow frequency band. Therefore, the main idea behind this work is to use this DNG cell for implementing a compact NBPF.

Because the particle is excited with electrical field perpendicular to the substrate, for better coupling, the transmission line above the particle is widened. In addition, this widening prevents gap size from being closer to the limits imposed by the fabrication technology (approximately 0.1 mm). The line is tapered next to the widened section for a better matching.

Particle resonant frequency is determined by its dimensions. Among the dimension parameters indicated in Figure 1(a), the side length of the loop, “$\alpha$” is the most important one on the resonant frequency. Figure 2 shows the resonant frequency variation of the resonator with respect to changing “$\alpha$.” In the simulation, three layers of Rogers 4003C substrate with relative dielectric constant ($\varepsilon_r$) of 3.55, thickness ($h$) of 0.813 mm, and loss tangent $\delta$ of 0.0027 are used and copper metallization thickness is 35 $\mu$m. To realize the passband at 1 GHz, the value of “$\alpha$” is set to be 12.9 mm.

While setting the gap size ($g_s$), it can be noticed that larger $g_s$ provides more suitable rejection up to the plasma frequency but results in a higher insertion loss within the

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**Figure 1:** (a) 3D layout of the DNG cell including quasi-planar chiral resonator (particle) electrically loaded to a microstrip line with series gaps. (b) Lumped element equivalent circuit and equivalent T-model.

**Figure 2:** The variation of the resonant frequency of the chiral particle with respect to changing “$\alpha$” (depicted in Figure 1). Other dimension parameters are set to $w = a/3$, $W_1 = 5.5$ mm, $C_l = 10$ mm, $C_w = 11.4$ mm, and $C_d = 1.4$ mm.
selectivity, a transmission zero is placed at 2.6 GHz using
has been improved.
frequency of the resonators, and the out-of-band rejection
thespuriousresponseoccursfarbeyondtwicetheresonant
improvement in filter performance is obvious. Also, the
the simulations results. Comparing to the results shown in
handed chiral resonator, respectively. Figure 4 also shows
The results obtained from equivalent circuit simula-
short ended stubs coupled with gaps to the wide sections of
passes which is depicted where the stubs (with coupling gaps) are modeled
LC resonators (Zstub). Appendix describes how to extract
These capacitors and inductors can achieve different resonant
3. Experimental Results and Discussions
Three layers of Rogers RO4003C are used to fabricate the
passband. On the other hand, smaller gs decreases the
rejection level within the stopband. In this design gs is set
to be 0.2 mm to lessen the influence caused by fabrication
uncertainties.
The results of full-wave electromagnetic and equivalent
circuit simulations of the structure shown in Figure 1(a)
are depicted in Figure 3, which clearly shows a narrow-
passband around 1 GHz (the equivalent circuit parameters of
the topology are extracted from equations (14), (15), and (17)-(19) of [4] and given in the caption).
To achieve a deeper rejection and also a sharper pass-
band, two DNG cells are cascaded as shown in Figure 4,
where cell I and cell II contain a left-handed and a right-
handed chiral resonator, respectively. Figure 4 also shows
the simulations results. Comparing to the results shown in
Figure 3, improvement in filter performance is obvious. Also,
the spurious response occurs far beyond twice the resonant
frequency of the resonators, and the out-of-band rejection
has been improved.
In addition, to expand upper rejection band and improve
selectivity, a transmission zero is placed at 2.6 GHz using
Figure 5: A DNG cell with loaded stubs; (a) layout and (b)
equivalent circuit.
Table 1: Comparison between this work and other published works.

| Ref. | Resonator    | $f_0$ [GHz] | FBW [%] | Length [$\lambda_g$] | IL [dB] |
|------|--------------|-------------|---------|----------------------|--------|
| [9]  | SRR          | 4.6         | 1.7     | 0.53                 | 5.2    |
| [8]  | EBG          | 5           | 3.7     | 0.47                 | 2.8    |
| [5]  | CRLH-CPW     | 5           | 6       | 0.42                 | 2.5    |
| [6]  | CSRR         | 1           | 8       | 0.42                 | 1.5    |
| [7]  | Multisection SIR | 2.4 | 10.8   | 0.24                 | 5.8    |
| This work | Quasi-planar chiral | 1 | 2.2    | 0.17                 | 5.1    |

This work uses a Quasi-planar chiral resonator to achieve compact size and high selectivity. The results are in line with other published works, showing that the proposed design is feasible for modern microwave communication circuits.

4. Conclusion

In this article, a narrow bandwidth bandpass filter based on the quasi-planar chiral resonators is presented. The proposed filter has the merits of simple design, backward propagation, compact size, and high selectivity. The results of equivalent circuit simulation, full-wave simulation, and measurement are in good agreement. Compared with other similar filters, it could be observed that the proposed filter has the advantages of better size integration and frequency selectivity. The proposed filter is feasible and applicable in modern microwave communication circuits.

Appendix

The input impedance ($Z_{in}$) indicated in Figure 5(b) at the resonant frequency of the quasi-planar resonator $\omega_{0,p}$ (where $Z_p = \infty$) can be written as $Z_{in} = \left[ (Z_0 + Z_s)/Z_{stub}/2 + Z_s \right]$. Hence, $Z_{stub}$ at $\omega_{0,p}$ is derived as

$$Z_{stub}(\omega_{0,p}) = \frac{2 \left[ Z_0 + Z_s(\omega_{0,p}) \right] \left[ Z_{in}(\omega_{0,p}) - Z_s(\omega_{0,p}) \right]}{Z_0 + 2Z_s(\omega_{0,p}) - Z_{in}(\omega_{0,p})}$$

(A.1)

$Z_{stub}$ is a complex amount whose real part describes losses which is ignored here for simplicity. Considering Figure 5(b), it can be obtained that

$$\Im (Z_{stub}) = j\omega L_{stub} - \frac{j}{\omega C_{stub}}$$

(A.2)

And the resonant frequency of $LC$ network is

$$\omega_{0,s} = \frac{1}{\sqrt{L_{stub}C_{stub}}}$$

(A.3)

Then, $L_{stub}$ and $C_{stub}$ can be extracted as

$$L_{stub} = \frac{\omega_{0,p} \Im \left( Z_{stub}(\omega_{0,p}) \right)}{\Delta \omega_0^2}$$

(A.4)

$$C_{stub} = \frac{\Delta \omega_0^2}{\omega_{0,p}^2 \omega_{0,s} \Im \left( Z_{stub}(\omega_{0,p}) \right)}$$
where

\[ \Delta \omega_0^2 = \omega_{0,p}^2 - \omega_{0,s}^2. \]  

(A.5)

**Competing Interests**

The authors declare that there is no conflict of interests regarding the publication of this paper.

**Acknowledgments**

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