Differences between Metamaterial coupled resonator filters with SRR and NBSRR

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Abstract

In this paper we study the differences in the frequency response using coupled Split-Ring Resonators (SRR) or coupled Non-Bianisotropic Split-Ring Resonators (NBSRR) in metamaterial band pass filters. The resonance frequencies are the same for a SRR or a NBSRR when both structures present the same dimensions. The difference between these two resonators is in the charge distribution at the first resonance frequency. Due to the topology, the charge distribution is different and this affects the coupling between adjacent resonators. This study is the starting point for the application of different coupled resonators in the design and implementation of metamaterial band pass filters.

1. Introduction

In the last decade, since Pendry proposed the SRR [1], the studies about the metamaterial transmission lines based on the dual line approach [2] and on the resonant approach [3] have been one of the most important research worldwide. One of the main reasons is the fact that the metamaterial structures can be used to implement different devices in a great spectral frequency range. In particular, the microwave and telecommunication fields have multiple applications such as filters [4], antennas [5] or lenses [6].

Some of the metamaterial works have been focused on the size reduction for the resonators [7]. This is due to the fact that, with the reduction of the resonators, a reduction in the dimensions of the device is obtained. Based on the SRR case, some of the proposed resonators present a greater or lower electrical length, as the Double Split Ring Resonator (DSRR) [8] and the Spiral Resonator (SR) [9], respectively. However, the Non-Bianisotropic Split-Ring Resonator (NBSRR) [8] presents the same electrical length as the SRR, that is, the first resonance frequency is the same for both the SRR and the NBSRR, when they present the same dimensions. The principal difference between the NBSRR and the SRR is the charge distribution at the first resonance frequency, which is shown in Fig. 1. Due to the charge distribution in the NBSRR, the cross polarization effects that appear in the SRR and that have been studied in [9] are eliminated.

Therefore, the objective of the present paper is the study of the difference between using coupled SRRs [10, 11] or coupled NBSRRs to implement metamaterial band pass filters.

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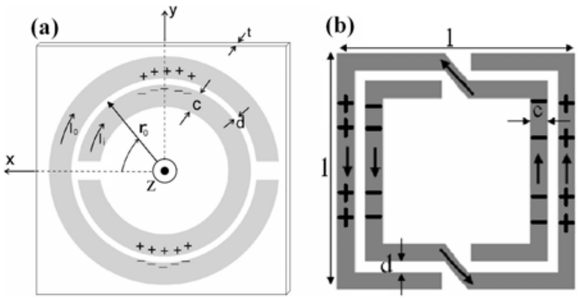

Fig. 1: Topology and charge distribution for the SRR (a) and the NBSRR (b)

2. Metamaterial filter with coupled resonators

In Fig. 2, the layouts and schematic models for metamaterial coupled resonant filters with three directly coupled resonators are shown. In the case with SRRs, only the external ring of each resonator is considered to be coupled to adjacent resonators. Although it is not exact, this approximation is reasonable since these inter-resonator couplings are the strongest and dominate the whole filter response. For the case of the NBSRRs, since no external rings can be identified, the dominant couplings are between the halves of rings that are external at each side. Therefore each ring is coupled to one adjacent resonator (or port) and with the other ring in the NBSRR. Both configurations of rings and couplings are schematized by the graphs in Fig. 2.

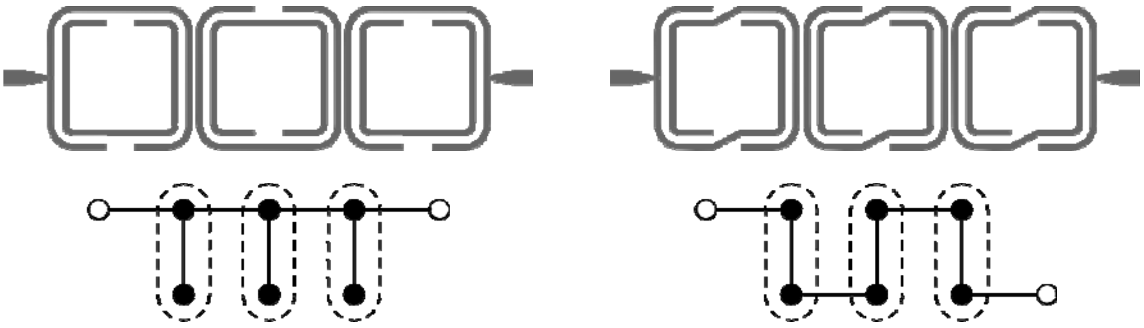
(a) (b)

Fig. 2: Basic layout and schematic graphs for a metamaterial coupled resonant filter with three SRRs (a) and three NBSRR (b). Black nodes represent rings, while dashed ovals indicate each complete resonator. Solid lines are couplings between resonators and with the filter ports (empty nodes).

Therefore, both filters are of sixth order. However, the coupling topology of the SRR filter, with three rings in the main path between the input and output port and one additional ring coupled to each one produces a triple order transmission zero. This transmission zero is located in the centre of the pass band, generating a dual-band response, where the bandwidth of the central stop band and therefore the separation between bands is controlled by the coupling between the two SRR rings [10]. This is not the case of the NBSRR filter, where the direct coupling, sixth order coupling topology gives rise to a regular filter with no finite transmission zeros. Frequency responses for electrical simulations of both filters, composed of coupled sections of transmission lines, are shown in Fig. 3. The responses are in full agreement with the theoretical analysis presented above. It should be noted that no efforts were made to optimize the filters responses, and that all the dimensions are equal for both models.

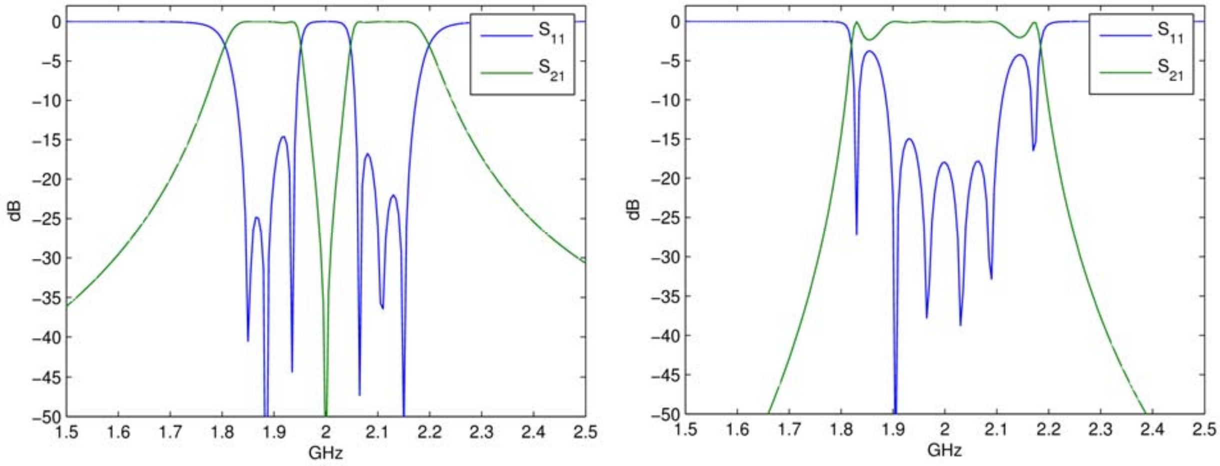

Fig. 3: Frequency response for a metamaterial band pass filter with three SRRs (left) and three NBSRRs (right), based on electrical models with coupled line sections.

3. Conclusion

In conclusion, this paper shows the differences on the coupling topology and charge distribution for a SRR and a NBSRR at their first resonant frequency. Due to these differences and despite of having the same electrical length, the use of these coupled resonators to implement metamaterial band pass filters, results on different frequency responses, with dual and single band characteristics for SRRs and NBSRRs, respectively. It should be noted that in any case the response order is double with respect to a conventional filter with open-loop resonators, resulting in an important footprint area reduction.

References

[1] J. B. Pendry, A. J. Holden, D. J. Robbins and W. J. Stewart, Magnetism from conductors and enhanced nonlinear phenomena, *IEEE Transactions on Microwave Theory and Techniques*, vol. 47, no. 11, p. 2075-2084, November 1999.

[2] G. V. Eleftheriades, A. K. Iyer and P. C. Kremer, Planar negative refractive index media using periodically L-C loaded transmission lines, *IEEE Transactions on Microwave Theory and Techniques*, vol. 50, no. 12, p. 2702-2712, December 2002.

[3] F. Aznar, M. Gil, J. Bonache and F. Martín, Modelling metamaterial transmission lines: a review and recent developments, *Opto-Electronics Rewiew*, vol. 16, no. 3, p. 135-145, September 2008.

[4] M. Gil, J. Bonache, and F. Martín, Metamaterial filters: a review, *Metamaterials*, vol. 2, no. 4, p. 186-197, Decembre 2008.

[5] J. Montero-de-Paz, E. Ugarte-Muñoz, F. J. Herraiz-Martínez, V. González-Posadas, L. E. García-Muñoz and D. Segovia-Vargas, Multifrequency self-diplexed single patch antennas loaded with split ring resonators, *Progress In Electromagnetics Research*, vol. 113, p. 47-66, 2011.

[6] M. J. Freire, L. Jelinek, R. Marqués and M. Lapine, On the applications of [mu]r=-1 metamaterial lenses for magnetic resonance imaging, *Journal of Magnetic Resonance*, vol. 203, no. 1, p. 81-90, March 2010.

[7] F. Aznar, J. García-García, M. Gil, J. Bonache and F. Martín, Strategies for the miniaturization of metamaterial resonators, *Microwave and Optical Technology Letters*, vol. 50, no. 5, p. 1263-1270, May 2008.

[8] J. D. Baena, R. Marqués, F. Medina and J. Martel, Novel small resonant electromagnetic particles for metamaterial and filter design, Proceedings of *International Conference on Electromagnetics in Advanced Applications (ICEAA)*, Torino, Italy, p. 439-442, 2003.

[9] J. D. Baena, J. Bonache, F. Martín, R. Marqués, F. Falcone, T. Lopetegi, M. A. G. Laso, J. García-García, I. Gil, M. F. Portillo and M. Sorolla, Equivalent-circuit models for split-ring resonators and complementary split-ring resonators coupled to planar transmission lines, *IEEE Transactions On Microwave Theory and Techniques*, vol. 53, no. 4, p. 1451-1461, April 2005.

[10] A. García-Lamperez and M. Salazar-Palma, Dual band filter with split-ring resonators, *IEEE/MTT-S International Microwave Symposium*, p. 519-522, June 2006.

[11] A. García-Lamperez, Analytical synthesis algorithm of dual-band filters with asymmetric pass bands and generalized topology, *IEEE/MTT-S International Microwave Symposium*, p. 909-912, June 2007.