Microstrip band-stop filter design from a modified version of the split ring resonator

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Abstract

A microstrip resonator is proposed for its use in planar band-stop filters. The structure of the resonator is based on a modified version of the split ring resonator (SRR). Thus, the proposed topology, called open interconnected split ring resonator (OISRR), provides a small electric size which is attractive for compact band-stop filter design. In order to demonstrate the resonance and band-stop characteristics of the proposed OISRR, we have designed and fabricated a filter to produce approximately a band-stop at 2 GHz. Electromagnetic simulation and measurement results between 300 kHz and 3 GHz are presented. A narrow band-stop is reasonably achieved with only one OISRR.

1. Introduction

Microstrip technology is essential in the design of modern communication systems since the development processes and materials are relatively economical. Moreover, the recent developments and challenges consist in designing and producing high-quality miniature components. Among the components that play an important role in communication systems, we can cite the filters and the metamaterial structures as the solution to reduce the size of the circuits. These last years, a great variety of ring resonators has been derived from the split ring resonator (SRR) because of the possibility to apply such structure to the planar technology and their potential applications in compact microwave filters [1-4].

This paper is focused on the implementation of compact narrow band-stop filters in microstrip technology. The band-stop response is achieved by connecting both accesses of the open split ring resonator (OSRR) to a microstrip transmission line section. Thus, we obtain an open version of the interconnected SRR (OISRR) which allows a parallel connection to a microstrip line section. An experimental filter has been optimized, fabricated and measured. The measured results show a reasonably agreement with the simulated ones.

2. Analysis of the filter

The structure of the proposed OISRR with band-stop characteristic is illustrated in Fig. 1. It is conceived from a conventional OSRR cell [3]. The dimension of the proposed structure is represented by five important parameters. At the top side, these are radius r of the external ring, width c of the ring conductor, slot s between rings and distance d of the microstrip line, which closes both rings. At the bottom side, we have a window $L_1 \times L_2$ without metallization etched in the ground plane. The microstrip width is adjusted along the window without metallization in order to preserve the characteristic impedance.

For coherence with proposed OSRR [3], Fig. 2 depicts the equivalent circuit of the OISRR excited by a microstrip transmission line. The microstrip transmission line has an characteristic impedance Z_c and an effective permittivity ε_{reff} . *RLC* series resonator parameters are connected in parallel to the microstrip transmission line section of length *d*. *R* and *L* values of the OISRR are the same than the classical SRR, and *C* value is four times the capacitance of the SRR with identical dimension and substrate (ε_r) values.

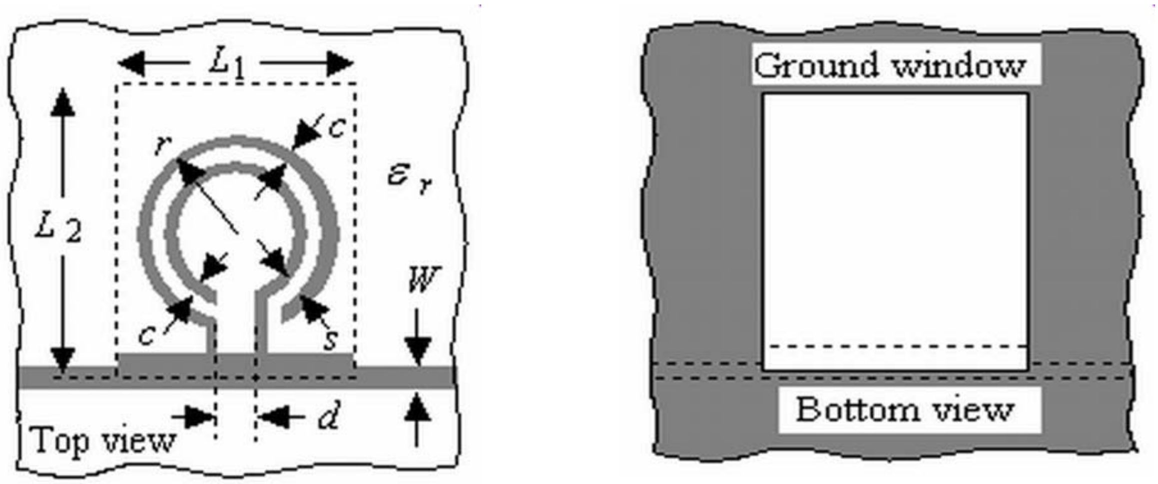

Fig. 1: Open interconnected split rings resonator (OISRR) excited by a microstrip line. (a) Top view. (b) Bottom view.

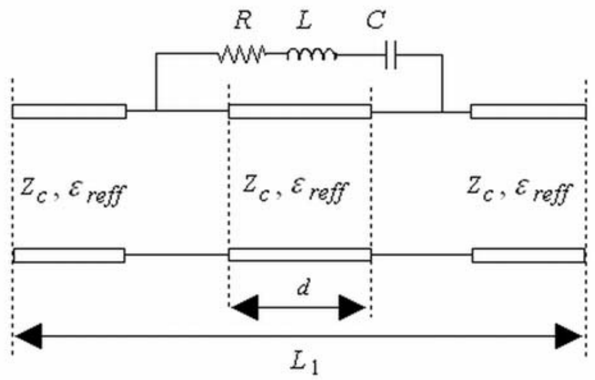

Fig. 2: Equivalent circuit of the OISRR connected to a microstrip line.

3. Results

To confirm and demonstrate the band-stop characteristic of the proposed filter (Fig. 1), we have fabricated and measured this with the help of the equivalent circuit of the Fig. 2. The Arlon AD1000 material with a dielectric constant ε_r =10.2 ($\text{tg}\delta = 0.0023$ at 10 GHz), substrate thickness $h = 0.635\,\text{mm}$, and copper thickness $t = 17.5\,\mu\text{m}$ has been used as substrate. The conductor strip has a width $W = 0.594\,\text{mm}$, corresponding to a 50 Ω microstrip transmission line. The structure of the Fig. 1 has been designed with the purpose to have approximately a resonance frequency at 2 GHz. The dimensions of the band-stop filter are $r = 2.2\,\text{mm}$, $c = 0.3\,\text{mm}$, $s = 0.25\,\text{mm}$, $d = 0.5\,\text{mm}$ and $L_1 \times L_2 = 9 \times 9\,\text{mm}$.

The experimental results, which were obtained from the Agilent E5070B vector network analyzer (VNA) and Anritsu 3680K on-microstrip test fixture calibrated from 300 kHz to 3 GHz, are shown in Fig. 3. They are compared with the results provided by a full-wave electromagnetic simulator (HFSS). It can be seen that the measured frequency response does not exactly match the simulated frequency response. This is due to the substrate and metallic losses, which were considered lossless during the simulations, to the measurement performance (uncertainties on S-parameters and repeatability errors), and also to the fabrication tolerances of the milling machine. On the other hand, the structure of the Fig. 1 behaves as a narrow band-stop filter. The resonance frequency is at 2.12 GHz and the stop-band is approximately of 0.018 GHz.

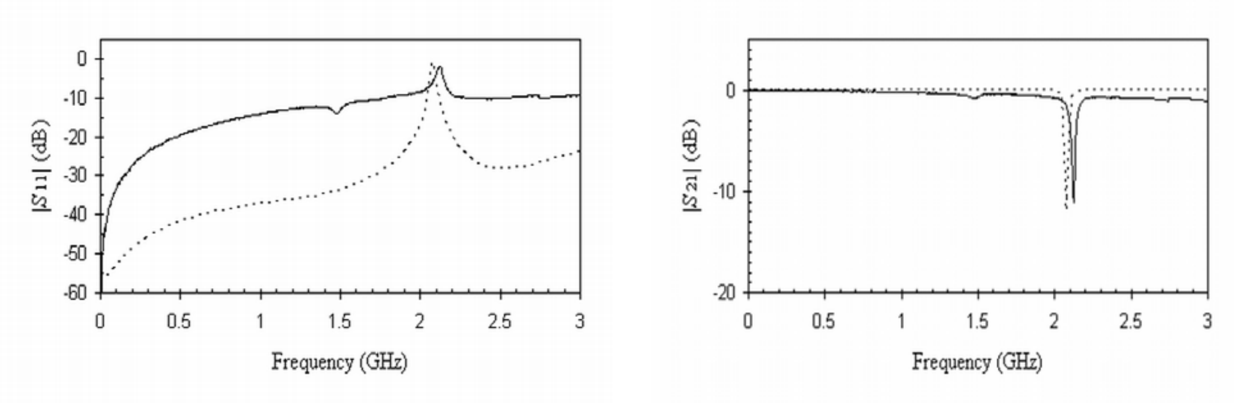

Fig. 3: Electromagnetic simulation (dashed line) and experimental (solid line) results of the band-stop filter.

4. Conclusion

An open version of the interconnected split ring resonator (OISRR) has been developed for compact narrow band-stop filter applications. This resonator provides a small size series *LC* element that connects in parallel to a microstrip line section. The OISRR has been applied to the design of a microstrip band-stop filter with a resonance frequency of approximately 2 GHz. The design was achieved by using a simple circuit model, and then fabricated and measured. Considering the tolerances of fabrication and the performance of *S*-parameter measurement bench, the electromagnetic simulation results show a reasonably agreement with the measurement results.

Acknowledgment

This work has been supported by Spanish Ministerio de Ciencia e Innovación under grant TEC2010-21520-C04-04/TCM.

References

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