Meander Open Complementary Split Ring Resonator (MOCSRR) Particles Implemented Using Coplanar Waveguides

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Introduction

Research on coplanar waveguide (CPW) structures has received considerable attention over the past few years. In particular, split ring resonators (SRRs), complementary split ring resonators (CSRRs) and open complementary split ring resonators (OCSRRs) [1]-[2] have been topics of interest. These structures have been applied extensively to left-handed transmission lines, power dividers, printed antenna arrays and filters [3]-[5].

This paper presents a new meander open complementary split ring resonator (MOCSRR) particle. This structure is based on the OCSRR particle published in [1]-[2]. For this work, the rings associated with the OCSRR particles are replaced with meander structures similar to the meander-loop resonator found in [4]. The result of this effort is a particle that resonates 26.5 % lower for dimensions that are the exact same overall dimensions as the OCSRR particle published in [1].

The MOCSRR particle introduced in this paper has many uses. One recently developed use is in the reduction of printed antennas [5]. By connecting OCSRR particles in series, a much smaller printed dipole for wireless applications can be designed. For example, this reduction of antenna size brings a huge design advantage in multiple input and multiple output (MIMO) communication systems, where multiple antennas are employed to increase the network throughput and coverage. Another useful application is in the wireless communication of implanted medical devices, where size plays an increasingly important role.

In the following sections, the MOCSRR particle is introduced and compared to the OCSRR particle. The equivalent circuit is extracted from simulations. This equivalent circuit is then successfully compared to measurements for accuracy.

The MOCSRR Particle

The MOCSRR particle is shown in Fig. 1 a) (shaded area represents copper). Instead of using slots in the form of concentric rings, a meander pattern is chosen. The two ports of the particle are attached to the top and bottom. The capacitance between the two ports is a result of the capacitance between the meander slots and the inductance is caused by the meander ring connecting the two ports. This results in an equivalent circuit of a capacitor C_{eq} connected in parallel with an inductor L_{eq}. The equivalent circuit is shown in Fig. 1 b).

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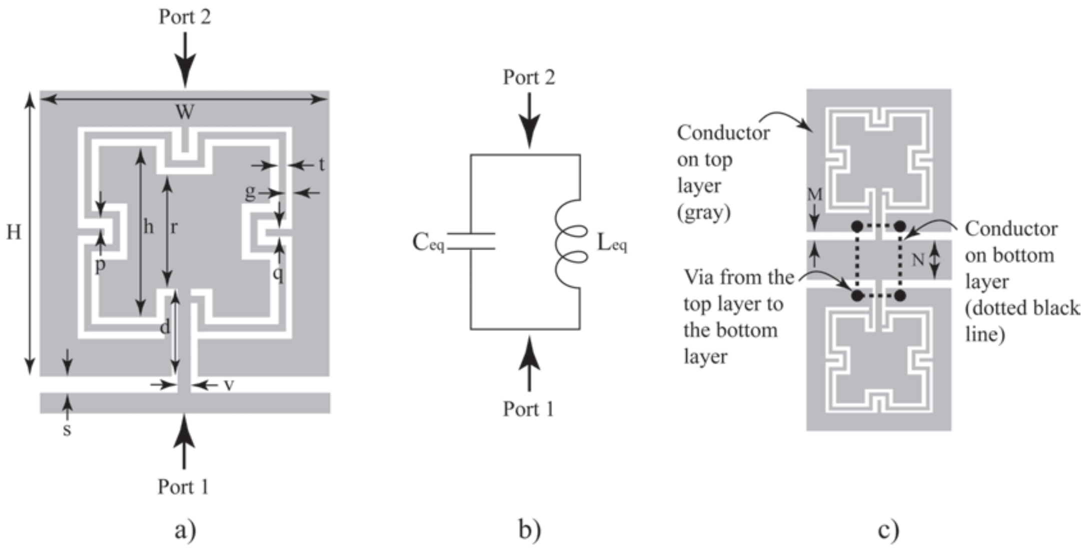

Figure 1: a) The meander open complementary split ring resonator particle (MOCSRR); b) the equivalent circuit of the MOCSRR particle; and c) CPW structure used to determine the resonant frequency of the MOCSRR particle using Momentum and measurements (W = 10.4 mm, H = 10.4 mm, s = 1.0 mm, v = 0.6 mm, d = 3.61 mm, h = 6.4 mm, r = 3.2 mm, t = 0.6 mm, g = 0.6 mm, M = 1.0 mm, N = 3.64 mm, p = 0.35 mm and q = 0.3 mm).

Modeling the MOCSRR Particle with an Equivalent Circuit

To extract the equivalent circuit, the CPW structure shown in Fig. 1 c) was simulated and tested. The host CPW transmission line has the same dimensions as the test circuit presented in [1] and a characteristic impedance of 50 Ω. Vias are used to connect the reference planes on each side of the signal trace to a conducting loop on the bottom of the substrate. This ensures that the two reference planes are at the same potential. Rogers Duroid 6010 ($\varepsilon_r = 10.2$, loss tangent = 0.0023 and d = 1.27 mm) was used as the substrate for the CPW structure in Fig. 1 c). First, Momentum [6] was used to simulate the CPW structure in Fig. 1 c). The values of S_{11} and S_{12} are shown in Fig. 2. When the MOCSRR particle resonated, most of the power flowed along the host CPW transmission line and S_{11} was reduced. A resonant frequency of 735 MHz was calculated from these simulations. Fig. 3 a) shows the top view of the surface currents at resonance (735 MHz). Notice that most of the surface currents are constrained to the host CPW transmission line. This indicates that the MOCSRR particles are resonating. Next, using curve fitting (similar to the technique in [1]) an equivalent circuit was extracted for the MOCSRR. The equivalent inductance was $L_{eq} = 9.25$ nH and the equivalent capacitance was $C_{eq} = 5.1$ pF. The values of S_{11} and S_{12} for the equivalent circuit are also show in Fig. 2. The simulations from Momentum and the equivalent circuit compare very well. Finally, the CPW in Fig. 1 c) was manufactured and the S-parameters were measured using a 4.5 GHz E5071C ENA series network analyzer by Agilent Technolgies. An image of the manufactured board being measured by the network analyzer is shown in Fig. 3 b). The measured values of S_{11} and S_{12} are show in Fig. 2. The measured results also compare very well with the simulation results. The measured resonant frequency was 714 MHz.

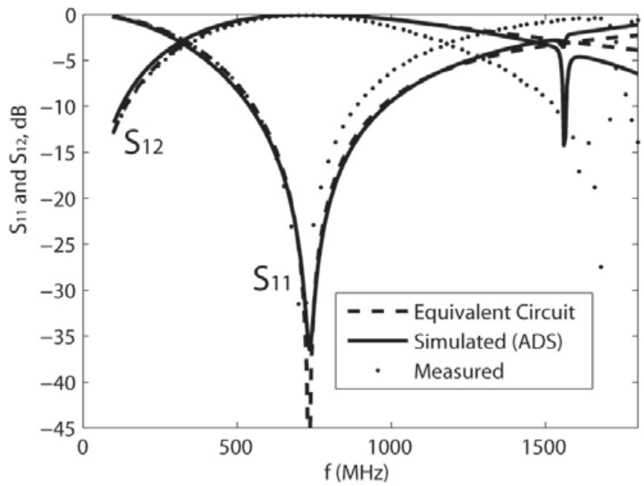

Figure 2: Simulated and measured values of S_{11} and S_{12}.

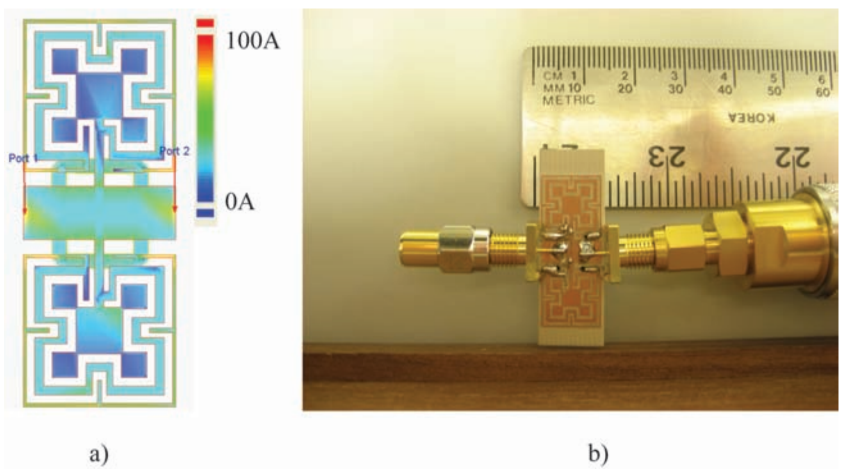

Figure 3: a) Top-view of the simulated surface currents at resonance; and b) Measuring the S-parameters of the MOCSRR particles.

Discussion

The overall dimensions of the MOCSRR particle in Fig. 1 are the same as the OCSRR particle introduced in [1]. The OCSRR particle presented in [1] resonated at approximately 1 GHz. The equivalent inductance and capacitance values computed for the OCSRR particle in [1] were 11.21 nH and 2.24 pF, respectively. The inductance of the MOCSRR particle presented in this paper is similar to the inductance of the OCSRR presented in [1], while the capacitance of the MOCSRR is about twice that of the OCSRR particle. This resulted in the MOCSRR particle resonating 26.5 % lower than the OCSRR particle in [1]. It is believed that this increase in capacitance is a result of the longer meander slots associated with the MOCSRR particle. This means that a reduction in size of the MOCSRR particle would increase the resonant frequency.

Conclusion

A new meander open complementary split ring resonator (MOCSRR) particle was presented in this paper. The resonant frequency for the particle was 26.5 % lower than an OCSRR particle with the same overall dimensions. The resonant frequency was determined by simulating a CPW test structure in Momentum, modeling the MOCSRR particle with an equivalent circuit and measurements. Good agreement was observed in all cases.

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