Development of A Rigorous Equivalent Circuit Model for Nested Split-Ring Resonator Structures

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Nested split-ring resonators (NSRRs) are a recent class of SRRs, which have been exploited in various different applications including antennas, filters, oscillators and sensors since they were first introduced in (R. Melik et al., IEEE J. Sel. Topics Quantum Electron., 16(2), 450-458, 2010.). They are primarily preferred due to their enhanced sensitivity compared to traditional SRRs, as well as their compact size, enabled by introduction of a higher number of opposing metallic strip pairs that constitute parallel split-rings through the continuous strip above. Presently, there are two types of NSRR geometries: The classical geometry (see Fig. 1-a), and the modified geometry (split into two freely moving and electrically connected halves for sensing displacement, see Fig. 1-b).

In this work, an equivalent circuit model which is valid for both NSRR geometries is developed. The parameters of the model are the capacitance and inductance of the parallel and opposing strips, the gap capacitance between the opposing strips, and the thin wire inductance for the modified geometry. Mutual inductances due to the interaction of each strip with those that are parallel to it and that oppose it are also included within the strip inductance. In the model, parallel strips are treated as coplanar waveguides with finite ground planes, and coplanar waveguide capacitance is used to calculate capacitance of parallel strips. The derivations of other parameters are also carried out using the formulas available in literature. The results of the model are compared to full-wave simulations and measurement results for varying number of strips (N). In the simulations and measurements, the change of the NSRR resonance frequency is observed versus the change of the gap between two modified NSRR halves (d in Figure 1), the length of the shorting wire (l in Figure 1), as well as the number of strips and physical dimensions of the structure. The results show an agreement, proving that the model is feasible.

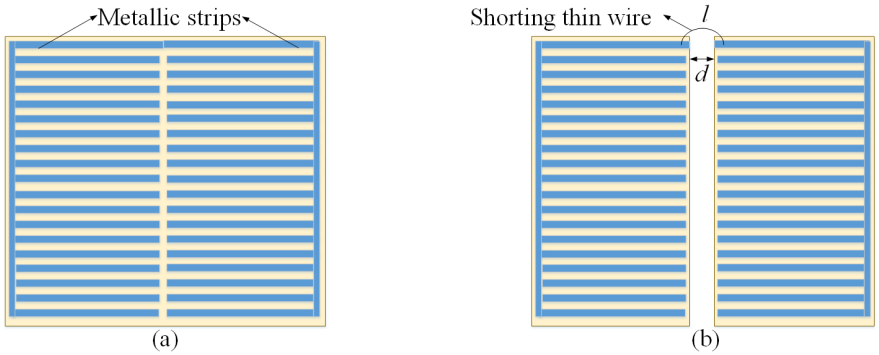

Figure 1: a) Classical NSRR geometry, b) NSRR geometry modified for displacement sensing.