Equivalent Circuit Modelling of Non-Symmetric Reciprocal Lossy Electromagnetic Structures

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I. Abstract

Lattice-network-based equivalent circuits of lossy symmetric reciprocal electromagnetic structures have shown superior performance when compared to other topologies like the T- or Π - networks [1]. This is due to the realizability of their elements and the orthogonal-mode decomposition, which, in most cases, provides a deep physical insight into the behaviour of the modelled structure.

However, to our best knowledge, the counterpart of the lattice network for non-symmetric structures is not available in the technical literature. One of the few approaches for this problem dates back to 1954 and was made by Felsen and Oliner [2]. This equivalent circuit accounts for the losses by means of a resistance and a conductance. An interesting aspect of this equivalent circuit is the use of two lossless transmission line sections to guarantee that these two lossy elements are positive at all frequencies. Two lossless immittances and an ideal transformer with real transformation ratio complete the equivalent circuit, but their realizability is not guaranteed.

More recently, in an attempt to somehow mimic the performance of the lattice network, two lattice-network-inspired equivalent circuits for non-symmetric electromagnetic structures have been proposed. The first one was proposed by Otto *et al.* [3] and includes two lossy immittances and four identical transformers. These transformers, with complex transformation ratio, account for the asymmetry of the structure. Obviously, this equivalent circuit degenerates into the lattice network for symmetric structures.

The second one was proposed by Abdo-Sánchez *et al.* [4] and it is based on the eigen-state formulation described in [5]. This circuit contains two lossy immittances and two ideal transformers with complex transformation ratios. Its topology, with two branches, is linked to the two eigen-value excitations. These eigen-value excitations correspond to the even and odd excitations in the case of symmetric structures, and thus the lattice network is recovered. It is possible, by introducing lossless transmission line sections, to guarantee that the transformation ratio is real and that the real parts of the immittances are positive. Although this is not a guarantee of realizability, it can be considered a desirable feature. Moreover, this reference plane shift provides power dissipation orthogonality in the two branches of the circuit.

The aim of this contribution is to provide a short description of these equivalent circuits and to compare their performances by modelling a misaligned complementary strip-slot element. None of them can guarantee the realizability of all their elements. Nevertheless, it can be concluded from the obtained results that lattice-network-inspired equivalent circuits are more convenient when the structure has two identifiable eigen-states, since they easily model the underlying physics of the structure. The modelling of this structure has also highlighted the better performance of the circuit based on the eigen-state formulation.

Acknowledgement

This work has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 706334, and from the Spanish Ministerio de Economía y Competitividad and the European Regional Development Funds under Grants TEC2016-76070-CR3-2-R and TEC2016-76070-CR3-3-R (ADDMATE).

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