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Semianalytic Analysis of a RIS Based on an Infinite 2D Array of Minimum Scattering Planar Antennas with Variable Reactance

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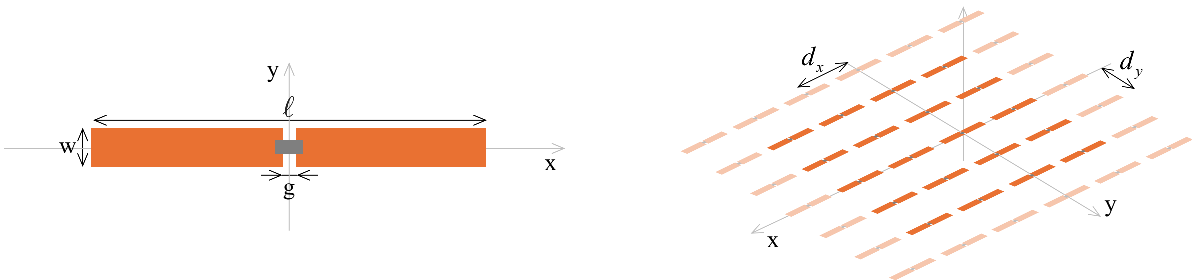
Reconfigurable Intelligent Surfaces (RIS) have emerged as a transformative technology for next-generation wireless communications and radar applications, enabling dynamic control of electromagnetic wave propagation. It is well known, however, that performances can be influenced by mutual coupling effects among the elements. Properly accounting for these effects can help maintain the reflective performance of densely packed RIS configurations. In this work, we analyze a RIS composed of an infinite Cartesian 2D array of planar antennas (either dipole or patch), each loaded with a variable reactance (see Fig.1). Under the assumption of minimum scattering antennas—which, in the framework of the method of moments (MoM) for periodic 2D structures, corresponds to considering a single unknown per antenna—we derive a semianalytic solution that provides both computational efficiency and fundamental physical insights. Unlike existing numerical approaches that rely on full-wave solvers or network-based formulations [1], [2], our methodology enables a transparent interpretation of the wave-structure interaction mechanism governing RIS performance. The analysis leverages Floquet mode expansion to systematically describe the mutual coupling effects between array elements, capturing how local reactance tuning influences global wavefront manipulation. This allows for a direct understanding of the connection between impedance modulation and the ability to shape reflection and scattering properties, revealing key design principles that might be obscured in purely numerical optimization frameworks. Compared to conventional numerical techniques used for RIS synthesis, such as multiport network theory [1] and scalable anomalous reflector models [2], our semianalytic approach offers a physically intuitive yet mathematically rigorous way to predict and control the radiation behavior of the surface. The derived formulation not only facilitates efficient parametric analysis but also lays the groundwork for the design of energy-efficient, reconfigurable metasurfaces with tailored beamforming capabilities. Preliminary results demonstrate the effectiveness of the proposed model in accurately predicting the electromagnetic response of the RIS while maintaining low computational complexity. Furthermore, we discuss potential extensions of this framework to finite-size RIS structures and the integration of real-time adaptive control mechanisms, which are crucial for practical deployment in smart radio environments and next-generation wireless networks.



(a) (b)

Figure 1. Geometry of the single printed dipole (a) with the lumped load at its center, and array arrangement (b).

References

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