Characteristic Mode Analysis of Knot Wire-Scatterers

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A knot is defined as a closed curve in space that does not intersect itself anywhere. Knot morphologies have gained rising interests in many fields such as fluid dynamics, polymer science, molecular biology, and electromagnetics. In electromagnetics, knot morphologies were proposed for many structures and devices such as Polarization Selective Surfaces (PSS) and antennas. The goal of this work is to quantify the electromagnetic response of knots using Characteristic Mode Analysis (CMA). The knots are assumed to be perfectly conducting, and their diameter is assigned to be much smaller than their total length to justify performing the CMA using the Method of Moments (MOM) formulation for Arbitrarily Thin Wires (ATW). For validation, the same knot structures were simulated using commercial solvers, as three-dimensional structures, and excellent agreement was achieved with the MOM formulation for ATW.

CMA has been recently proposed for designing and optimizing antennas and scatterers with different shapes and in different environments. At any frequency, CMA decomposes the total current on the scatterer in terms of a weighted sum of its fundamental current modes. The weight of each mode is explicitly provided by the characteristics angle or the Modal Significance (MS_n) which depends on the shape, size, material properties and the environment of the scatterer. Using MS_n, the resonance frequency and the bandwidth of each mode can be determined, whether it is explicitly expressed in the scattered fields or not due to a particular excitation. In this work, CMA of knots wire scatterers with different types is presented to correlate the symmetries and shape properties of each knot category with the overlap, resonance frequency, and bandwidth of the fundamental modes of the knot structure. Several examples of how the CMA of these knot structures facilitates the design of novel antennas and scatterers are also discussed.