Spontaneous breather generation in model binary metamaterials

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The last decade, the study of metamaterials, i.e., of artificially structured materials that exhibit electromagnetic properties and functionality unattainable from natural materials, has attracted great attention. A specific class of metamaterials that exhibit significant magnetic properties at Terahertz and optical frequencies is represented by the magnetic metamaterials [1, 2], which are customarily comprised of regular arrays of split-ring resonators. Real-time dynamic control over the effective metamaterial parameters is of great importance for potential applications. That lead to the construction and detailed study of nonlinear metamaterials, which found to be dynamically tunable by varying the input power [3].

The nonlinearity, along with the inherent discreteness of the metamaterials, allows for the excitation of intrinsic localized modes or discrete breathers [4, 5], i.e., spatially localized, time-periodic and stable excitations that may be produced generically in discrete lattices of weakly coupled nonlinear elements. Discrete breathers may appear spontaneously in a lattice either statistically or by a purely deterministic mechanism that relies on a fundamental instability for wave propagation in nonlinear media (modulational instability).

Recently, a novel magnetic metamaterial comprised of two types of split-ring resoantors was investigated theoretically and it was demonstrated that in the nonlinear regime it is well suited for the observation of phase-matched parametric interaction and enhanced second harmonic generation. The binary structure of the split-ring resonator lattice allows for generation of breathers through direct external induction by a frequency-chirped incident field [6, 7, 8]. That method has been applied succesfully for dissipative breather generation in experiments on di-element cantilever arrays [9]. We have generated numerically a variety of high amplitude dissipative breathers by frequency chirping of the driving field in a model nonlinear binary magnetic metamaterial, and we demonstrated their stability that results from a delicate balance between the input power and the intrinsic losses. These breathers may exist either in the bulk or at the surface of the metamaterial, and they modify locally its magnetic response.

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