Dissipative Discrete Breathers in rf SQUID Metamaterials

N. Lazarides*, G. P. Tsironis, M.Eleftheriou

Department of Physics, University of Crete, and Institute of Electronic Structure and Laser, Foundation for Research and Technology – Hellas, P. O. Box 2208, 71003 Heraklion, Greece

* Electronic Address: nl@physics.uoc.gr

The developement of artificially structured, composite materials (metamaterials) have substantially extended the range of possible electromagnetic response that can be obtained by naturally occuring materials. For example, some magnetic metamaterials (MMs) exhibit significant magnetic properties at Terahertz and optical frequencies, as well as negative magnetic response at far-infrared frequencies. It has been recently suggested that rf SQUID (i.e., superconducting quantum interference device) arrays in an alternating magnetic field can operate as nonlinear MMs in microwaves [1], leading to negative magnetic response above the resonance frequency of its constituent elements. The nonlinearity, which is intrinsic to each rf SQUID due to the presence of the Josephson junction, provides the possibility of tuning the magnetic permeability of the MM by varying the applied flux.

Moreover, the combined effects of nonlinearity and discreteness may lead in the generation of nonlinear excitations of the form of dissipative discrete breathers (DDBs), i.e., spatially localized, time-periodic, and stable excitations, whose dynamics is governed by power balance between losses and external driving field. The existence and stability of DDBs in rf SQUID arrays is investigated numerically. We analyze several DDB excitations, both in one and two dimensions, which are linearly stable up to relatively large coupling parameters. We find that DDBs may locally alter the magnetic response of the array from paramagnetic to diamagnetic (or vice versa), and that they are not destroyed by increasing the dimensionality [2].

Those DDB excitation exhibit some similarities with those appearing in other systems whose elements are coupled magnetically, which are usually referred to as magneto-inductive systems. For instance, DDBs may appear in MMs comprised of nonlinear split-ring resonators [3, 4]. However, there are distinct differences between DDB excitations in those systems, due to the different form of the nonlinear onsite potential. Given that both nonlinear systems have been constructed in the laboratory [5, 6], our theoretical predictions are experimentally testable.

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