Experimental topological physics with coaxial cable networks

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Abstract

Topological physics is concerned with the classification of random matrices defined on graphs, where the matrix elements correspond to the edge weights. In the physics context, these matrices represent Hamiltonians, whose eigenvalues constitute the energy states of the system. The key classification question concerns the null space of these matrices: can two Hamiltonians be connected by a continuous transformation of the edge weights, without increasing the size of the null space? If they can, they are defined to have the same topology.

We show that coaxial cable networks, operating at radio-frequencies, provide a simple physical system for experimental studies of these topological properties. The voltages at the nodes of the networks are determined by a matrix eigenvalue problem, which maps onto a graph with the same connectivity as the network and edge weights determined by the impedances of the corresponding cables. By swapping in cables of different impedances, we can investigate the properties of an ensemble of random instances of the matrix representing a given graph.

We have mainly explored the properties of bipartite graphs, which map onto the chiral symmetry class of random matrix theory. These may have zero energy states because the chosen impedances give a matrix which falls on a topological boundary, but they can also have states which are at zero energy regardless of the impedance values. Such topologically protected states most simply occur when the number of vertices of each type on the bipartite graph is different. However, we also demonstrate the existence of protected states for certain balanced graphs.