Exceptional Points of Degeneracy induced in Linear Time-Periodic Systems

Hamidreza Kazemi*, Mohamed Y. Nada, Tarek Mealy, Ahmed F. Abdelshafy, and Filippo Capolino
Department of Electrical Engineering and Computer Science, University of California, Irvine, California 92697, USA

The splitting point of degenerate resonance frequencies varying a system parameter is referred to as an exceptional point of degeneracy (EPD) and it emerges in a system when two or more eigenmodes of the system coalesce into a single degenerate eigenmode in both their eigenvalues and eigenvectors. The surge of interest towards the EPDs concept has led to finding different and unique properties associated with the emergence of these points in the systems which has various potential applications such as enhancing the gain of active systems (M. A. K. Othman, et. al. *Phys. Plasmas*, 23, 033112, 2016.), directivity in antennas, and enhanced sensors (J. Wiersig, *Phys. Rev. Lett*., 112, 20, 203901, 2014), etc.

We present a general theory of exceptional points of degeneracy in periodically time-variant systems, in analogy to the EPDs found in spatially periodic structures, that do not necessarily require the presence of loss or gain. We show that even a single resonator with a time-periodic component develops EPDs. As an example, we demonstrate the concept using the simplest possible resonator, i.e., an LC resonator, though the formalism is general and applicable to any time periodic photonic or radio frequency system. We also demonstrate the conditions for EPDs to exist in time-periodic systems that are either lossless/gainless or with loss and/or gain and we show that a system with zero time-average loss/gain exhibits EPDs with purely real resonance frequencies, yet the resonator energy grows algebraically in time. Here we focus on temporally induced EPDs for possible sensing applications due to their extreme sensitivity to small changes in the system which lead to a detectable shift in the system observables like resonance frequency or quality factor.