Exceptional Points of Degeneracy and Their Applications in Arrays, Oscillators and Sensors

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There are various kinds of degeneracies in electromagnetic systems and we discuss here an important class of them: the case when two or more eigenstates of a system coalesce. Such degeneracies can happen in circuits, resonators (i.e., coupled LC resonators, electromagnetic cavities, etc.) and multimode waveguides. We do not discuss the otherwise common concept of two independent modes in a waveguide that have the same wavenumber. We discuss systems where the degeneracy also involves polarization states, and this can happen in a surprisingly large number of systems. Such degeneracies occur in systems that can be fully passive or in systems that include gain elements; we discuss the common aspects of these two classes. The number of coalescing eigenmodes determines the order of the degeneracy.

For example we explore the concept of array of antennas arranged periodically and sequentially fed by two coupled transmission lines, under the special condition known as the exceptional point of degeneracy (EPD) at which two or more of the supported eigenmodes of the system coalesce. We investigate different radiating array structures capable of exhibiting EPDs in their dispersion diagram. In particular we will explore a few kinds of EPDs called, the regular band edge, the stationary inflection point and the degenerate band edge, etc.

Besides the fundamental concepts, we will also provide various experimental verifications of the occurrence of EPDs in resonators and waveguides. We will discuss possible applications in the area of oscillators, antenna arrays, amplifiers, delay lines, etc.

In the second part of the talk we will discuss how the concept of EPD is useful to conceive very high sensitive systems that can pave the way to a new scheme of high-sensitive sensors. Indeed, it has been apparent that resonant frequencies in a system with EPD are extremely sensitive to a perturbation. Therefore observing a frequency shift in resonators or in oscillators based on EPDs, is an indicator of an applied physical, chemical or biological perturbation. Systems of EPDs can be realized using gain and loss (usually referred as EPDs induced in PT symmetric systems), time modulation of a component, etc. We will provide the experimental demonstration of such extremely sensitive systems.

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His research interests include applied electromagnetics in general, sensors in both microwave and optical ranges, photonics, microscopy, metamaterials and their applications, traveling wave tubes, antennas, propagation, wireless systems, chip-integrated systems, etc. He is an IEEE Fellow, and he is the editor of the two volume “Metamaterials Handbook”.