Multimodal Waveguides With Exceptional Points of Degeneracy of Various Degrees

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We present a formulation and theoretical aspects relative to multimodal propagation in guiding systems and how it is possible to design such waveguides to exhibit a degeneracy condition of order 2, 3 and 4. In this presentation we adopt a multi transmission line (MTL) approach for investigating the wave dynamics in waveguides with degeneracies; that includes inductive and capacitive per-unit-length coupling. Such degeneracies, explored in the state space of a guiding system, refer to points at which two, or more, physical eigenstates (eigenvalues and eigenvectors) coalesce into one. All the degeneracies considered here are under the same notion of exceptional point of degeneracy (EPD), and include some of the previously studied degeneracies like the stationary inflection point (SIP) and the degenerate band gap (DBE). The concept of EPD is explored here first in lossless coupled waveguides or coupled resonators and then with the inclusion of losses showing how such EPDs are deteriorated.

EPD of various orders can be realized in microwave and optical frequencies, based on lumped circuits, microstrip transmission line technology, metallic slow-wave structures for high power applications, and optical coupled-resonator waveguides. Remarkably, we illustrate how EPDs may deteriorate when detuning the parameters of the system. The aforementioned EPDs in such realizations demonstrate unprecedented performance, namely (i) giant scaling of the Q factor near the EPD, (ii) giant resonances, (iii) giant amplification and low-threshold oscillations. Especially, the oscillation threshold depends on the order of the EPD, yet we also show the impact of the tolerances and losses on the threshold. Some practical applications include loss-induced transparency, sensors, and high power generation, to name a few.