Ultrasensitive Parity-Time Symmetric Wireless Microsensors

Mehdi Hajizadegan and Pai-Yen Chen,

Department of Electrical and Computer Engineering, Wayne State University,

Detroit, MI, 48202, USA.

In the internet-of-things (IOTs) era, a great number of passive wireless sensors have been proposed to measure miscellaneous quantities, such as pressure, temperature, and chemical reactions. Most of these sensing devices which are based on the passive LC oscillating circuitry, such as the microelectromechanical and application-specific integrated-circuit sensors, which sometimes have low quality factor (Q-factor) due to the extremely miniaturized device dimensions, insignificant skin-effect of thin metals, and resistive losses of packaging and electronic materials. In this talk, we will present an ultrasensitive parity-time (PT)-symmetric wireless sensor, which offers a sharp-peaked, narrow-band resonance, even after considering losses in the device, package, and background medium. First, we theoretically show that a wireless sensor with the specific PT-symmetric equivalent circuit, which are realized with properly balanced gain and loss, can exhibit purely real eigenfrequencies for its non-Hermitian Hamiltonian, and, in particular, high-Q (narrow-band) and unidirectional reflectionless properties. We have designed and fabricated an inductively-coupled wireless intraocular pressure (IOP) microsensor, which were measured by a conventional passive coil antenna and an active PT-symmetric device obeying the PT-symmetric topology. Our experimental results show that the PT-symmetric wireless sensor coupled with an active reader can display significantly enhanced modulation depth and frequency shift in terms of the measured S_{11}, when compared to common passive wireless sensors. Further, by varying the Hermicity (e.g. Q-factor) and coupling strength (e.g. mutual inductance) of this PT-symmetric electronic system, we have experimentally characterized that the broken PT-symmetric phase (with complex eigenfrequncies associated with purely amplification/attenuation effect) and the exact PT-symmetric phase, with a transition called spontaneous PT-symmetry breaking point, which are in good agreement with theoretical calculations. Our results pave a promising way towards reliable, high-sensitivity, loss-resistant implantable microsensors, including but not limited to intraocular pressure sensors, intracranial pressure sensors, and intravascular pressure sensors, to name a few.