Low-Interference Harmonic Transponder Sensors Using Graphene Electronics

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Internet of things (IoTs) and ubiquitous sensor networks are rapidly emerging fields of study that potentially merge the ever-improving, ever-expanding wireless technology and micro/nano-technology. However, the heterogeneous integration with other electronic modules on a networked sensor node, such as the silicon-based sensor and the radio-frequency (RF) modulator, remains challenging due to compatibility and integration issues. In this talk, we propose the fully-passive harmonic transponder sensors (harmonic sensors) for wireless detection of (bio-)chemical responses with low electromagnetic interferences and noises. A harmonic sensor, which transmits an RF signal at the fundamental frequency and receives its second harmonic, can greatly suppress clutters and returned echoes that limit the sensing performance.

The proposed harmonic sensor comprises a chemically-sensitive frequency modulator based on the graphene field-effect transistor (GFET) circuit, which is capable of directly modulating the RF carrier signal when exposed to the target (bio-)chemical agents. We have experimentally demonstrated the concept and implementation of a GFET-based sensing modulator (with an electrical bias) through the frequency modulation (FM) experiments conducted for PH sensing. Our results clearly show the FM effect, namely the second harmonic generation effect. Further, the frequency conversion efficiency is very sensitive to the GFET's charge neutral point that is a linear function of the PH value of background medium. As a result, (bio-)chemical sensing and frequency modulation can be deliberately combined within a single RF module. The experimental results were also used to develop and validate the physics-driven compact model for RF circuit simulations. We have theoretically demonstrated the possibility of making a fully-passive, all-graphene harmonic sensor, comprising the single/double-balanced GFET circuit and the dual-band graphene antenna. This graphene-based harmonic sensor may have great potential for making an ultracompact, battery-free nodal architecture with low detection noises, enabling continuous, real-time event-based monitoring in pervasive healthcare IoTs, ubiquitous security systems, and other wireless wearable and bioimplant applications.