A Compact Harmonic Sensor Based on a Dual-Resonant Microstrip Antenna Loaded with a Microfluidic Channel

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Wireless sensing and tracking systems based on modulated backscattering principle have attracted tremendous attentions in fields, ranging from radio-frequency identification (RFID) and internet-of-things (IoTs), to smart cities and smart manufacturing. Recently, passive harmonic-transponder sensors (or harmonic sensors), inspired by the concept of nonlinear harmonic radar, have gaining popularity thanks to their robustness to clutter, jamming, and electromagnetic interferences in the rich-scattering environment. In this talk, we propose and experimentally demonstrate a miniature harmonic tag, consisting of a compact, dual-resonant elliptical microstrip patch antenna connected to a diplexer and a frequency doubler; All these devices are accommodated on the same printed-circuit board. Such a nonlinear harmonic tag can receive a microwave signal with the fundamental frequency (f_0) and efficiently re-transmit its second harmonic ($2f_0$). Specifically, by carefully choosing the feed position, the basic even and odd modes (i.e., TM_{e11} and TM_{o11} modes) with orthogonal intracavity field profiles can be excited at f_0 and $2f_0$, respectively. Moreover, if a microfluidic channel is placed underneath the microstrip patch, the conversion loss can be sensitively modulated by the effective dielectric constant changes in the microfluidic channel. By properly designing the microfluidic channel, the dielectric constant perturbation may shift only the second resonant peak, while having no effect on the first resonant peak. Therefore, the magnitude of second-harmonic outputs can reflect the dielectric constant changes of the carrier fluid or gas. We will present the eigenmodal analysis and numerical validations for the design of dual-resonant elliptical patch antennas. Our measurement results affirm the theoretical results, showing that this simple and low-profile microstrip antenna exhibits dual resonant modes at the desired frequencies, with satisfactory broadside gain and impedance matching. Our work shows that the harmonic tag integrated with a microfluidic channel may pave the way towards a new class of passive harmonic-transponder sensor.