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Investigation of electromagnetic coupling between the antenna and split-ring-based metasurface in CMOS technology

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Physics of coupling of resonating structures has been investigated for many decades, yet still new effects are discovered due to the better understanding of the underlying processes and due to the shift of the focus from the classical resonators to the quantum objects, to meta-atoms and to the nanoscale in general. The well-known effect in atomic physics of the electromagnetically induced transparency was recently demonstrated with optical metamaterials stacked together. It became feasible to realize a near-field sensor based on coupled resonators for detection and spectral analysis of different 2-D materials, chemical compounds, or biological materials and structures thanks to the dramatic increase of coupled resonators' sensitivity to the changes of the electromagnetic properties of the surrounding medium. Furthermore, this concept can be efficiently implemented using the technology platform which is offered by the well-developed mainstream silicon (Si) complementary metal-oxide-semiconductor technology (CMOS). It is commercially available, reliable, and due to the extended metal stack's functionalities, providing many possibilities for designing high-frequency components. For example, 90-nm Si CMOS technology served as a platform for designing a terahertz (THz) sensor of human body-emitted radiation in a broad range of frequencies 0.1-1.5 THz. In this paper we report on the investigations of electrodynamic properties of a metasurface-coupled THz antenna with the fundamental resonance frequency of 350 GHz which is implemented in a 180-nm CMOS technology.
The structure under investigation is essentially a THz detector based on a pair of n-type CMOS transistors. The detector is equipped with a differential slot antenna with an outer diameter of 450 µm. A single split-ring resonator has a size of 65×30 µm with a gap of 10 µm. The numerical simulation of the electromagnetic properties of coupled resonators was performed by the Finite Element Method in CST Studio Suite. The experimental measurements were performed with the use of the frequency-domain terahertz platform with the CW THz source based on a photomixer of the TOPTICA's Terascan platform. When both antenna and a split-ring are placed together and their resonance is tuned to the same frequency, the electro-magnetic coupling between them results in strong shifting of peak frequencies. One peak shifts towards the lower frequencies, another towards the higher ones. 42% splitting from the initial resonance frequency was recorded. When the antenna is coupled to three split-rings the peaks shift even further from each other. If the antenna is coupled to a whole system, a metasurface of split-rings, then the 58% splitting from the resonance frequency was recorded.
Summarizing this report, we show that the efficient electromagnetic coupling between the slot antenna and the metasurface of split-ring resonators can be realized in a commercially available 180-nm CMOS technology.

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