Development of Sub-Millimeter Wave Graphene Switched Antennas

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Multiple-Input-Multiple-Output (MIMO) antenna arrays have been attractive both for imaging and communication applications in the sub-millimeter-wave (sub-mmW) region (>100 GHz). Specifically, sub-mmW large-aperture, multi-element MIMO arrays can perform high-spatial-resolution imaging exploiting the small wavelengths of these frequencies. However, as frequency increases, the implementation of such configurations is halted by the complexity and losses of the feeding networks (e.g. Butler matrices). As such, the use of passive devices, including couplers and power dividers, leads to excessive losses and complex systems. For that purpose, we aim to replace the bulky/lossy feeding networks, with coded apertures, comprised of switch reconfigurable antennas that simultaneously transmit orthogonally modulated wavefronts. In this manner, the receiver can demultiplex the transmitted signals using the orthogonality between different waveforms. This coding scheme is well established in microwaves and can be carried out using reconfigurable switches (or phase shifters) embedded with each antenna. Such switches are available in microwave frequencies (e.g. CMOS transistors), however, in the sub-mmW region, these technologies increase the cost of fabrication dramatically, due to their complexity and on-wafer real estate. Therefore, we plan to use graphene to carry out the switching, by embedding a graphene-based-switch on each antenna. Exploiting the tunable graphene properties, we can develop low-profile dynamically reconfigurable switches. Namely, the sheet-impedance of monolayer graphene can be regulated from 1500 Ω/□ (Ohm per square) to 300Ω/□, using external biasing electrodes. In addition, recent fabrication advances, enable the development of multiple graphene devices over a large area with high-yield, necessary for the implantation of large-scale coded MIMO arrays.

To design the proposed coded MIMO configuration, we embed graphene switches on each antenna. Herein, we use actual graphene sheet-impedance measurements, instead of theoretical carrier transport modeling, thus we provide a more accurate performance estimation of the proposed configurations. To design the antenna topology, we initially plot the antenna currents without the use of a switch. Then, we optimize the graphene switch position to achieve maximum ON/OFF ratio, while optimizing radiation efficiency. The tradeoff between these two metrics (switching and radiation performance) is a limiting factor that we have to compromise to meet the design criteria. Namely, low switching ratio leads to poor code orthogonality, thus undermining the demultiplexing process. On the other hand, low radiation performance leads to poor signal-to-noise ratio on the receiver. Hence, we optimize the antenna topology and switch position to meet the design specifications.