Electrically-Shaped Liquid Metals in 1- and 2-D for Reconfigurable Apertures

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Reconfigurable antennas have conventionally used semiconductor or MEMS switches to alter the currents on the antenna and thus, their radiation properties. More recently, a number of macro-scale physical reconfiguration methods have been proposed, including moving fluids and sliding, rotating, or bending substrates to change a loading condition. Physically reconfigurable devices require motion over a much larger distance and thus cannot compete with the fast switching of a semiconductor switch. However, for applications where sub-millisecond switching is not required, the ability to generate a large-scale geometric change achieves a greater range of antenna properties while improving power handling relative to lumped element loading. Although liquid metals are typically actuated via pneumatic means – pumps or manually-generated pressure via syringes – the metal can also be shaped electrochemically. This approach requires only a DC circuit rather than a microfluidic "circuit", simplifying control and integration into electronic systems.

In this paper, we describe our recent work using a new electrochemical method for reversible, pump-free control of liquid eutectic gallium and indium (EGaIn) in capillaries and 2D surfaces. A DC bias allows deposition (or removal) of a surface oxide on the EGaIn, which alters the metal's surface tension. These variations then enable electrically-controllable and reversible flow in capillaries. Using this approach, we have developed both polarization and frequency reconfigurable linear antennas in configurations with as many as four simultaneously controllable capillaries. Our measurements indicate that these devices possess a much higher tuning ratio than lumped element-based reconfigurable antennas, while also producing a more linear response and higher power handling capability. Finally, we will present our most recent results for a reconfigurable reflectarray element consisting of a liquid metal reflector that is shaped in 2D dimensions using electrical bias.