Paraffin-Based RF Microsystems for Millimeter Wave Reconfigurable Antennas

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With an increasing demand for high-speed wireless communication, current wireless infrastructure cannot provide the bandwidth required for simultaneous high-speed data transfer for multiple users. The next generation of millimeter-wave (mmW) communication systems operate in the frequency range of 30–300 GHz and can provide a bandwidth of more than 3 GHz. In addition, these systems rely on adaptive strategies to achieve high data-rate communication which requires reconfigurable elements. In our research, we introduce a new class of reconfigurable radio frequency (RF) microsystems using paraffin phase-change material (PCM) that enables low-loss reconfiguration for mmW components. Paraffin (alkane) is a low-loss nonpolar dielectric with a loss tangent of 6.6×10^{-4} at 110 GHz that undergoes a 15% reversible volume change through its solid to liquid phase transition. Using this unique combination of loss characteristics and mechanical properties, we have developed continuously variable capacitors. These electro-thermally actuated variable capacitors are very low-loss at mmW band and can be monolithically integrated with antennas and RF components to introduce reconfiguration.

In this work, we present a frequency reconfigurable slot antenna which covers the 94 GHz–102.2 GHz band. This is an extension of our previous work (B. Ghassemiparvin, S. Shah and N. Ghalicehchian, EuCAP 2017). In order to achieve reconfiguration, the slot antenna is loaded with two paraffin PCM capacitors. The capacitors are actuated using joule heaters and with the increase in temperature, paraffin goes through a solid-liquid transition. As the volume of the paraffin increases, the capacitance decreases continuously by approximately 15% which results in increasing the resonance frequency. The gain of the antenna at 100 GHz is 3 dBi and it is approximately constant over the reconfiguration range. The Efficiency of the antenna is > 72% for the entire reconfiguration range which is due to the low dielectric loss of the paraffin. Series resistance of the paraffin PCM capacitors is calculated to be less than 0.7 Ω which is significantly less than the semiconductor-based variable capacitors such as GaAs Schottky diodes (4–10 Ω).

Fabrication is carried out using a six-layer photolithography process which paraffin PCM capacitors are monolithically integrated with the antenna. For the deposition of the paraffin an in-house fabrication process based on spin coating is developed. The details of the design, fabrication and measurement results will be presented at the meeting.