MM-Wave Beam Scanning Focal Plane Arrays Using Microfluidic Reconfiguration Techniques

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Microfluidic based reconfiguration techniques have been recently shown to provide superior advantages in terms of high power handling capability and wideband tuning range. More recently, our group has introduced the concept of microfluidic based focal plane arrays (FPAs) as a low cost implementation of high gain beam scanning mm-wave arrays (A. Gheethan, R. Guldiken, and G. Mumcu, "Microfluidic Enabled Beam Scanning Focal Plane Arrays," Presented at the IEEE APS/URSI International Conference, Orlando, FL, 2013). Specifically, our recent work has demonstrated this concept through the design and experimental verification of a 30GHz 1D FPA. The FPA was constructed as a microfluidic channel and placed at the focal surface of an 8cm diameter extended hemispherical microwave lens. A small volume (2.5μL) of liquid metal inside the microfluidic channel acted as a patch antenna and provided the beam scanning functionality when physically moved through the use of a bi-directional micropump unit. Most importantly, the feed network of the FPA was strategically designed to be all-passive by making use of half-wavelength microstrip line resonance mechanisms. Consequently, this all-passive feed network alleviated the need for RF switches and resulted significant reduction in implementation complexity and associated cost as compared to a conventional switched FPA. The microfluidic channel of the FPA was molded inside Polydimethylsiloxane (PDMS). To reduce the substrate loss, the PDMS mold was sealed by a 4mil thick liquid crystal polymer (LCP) layer. The microchannel assembly was placed over a 5mil thick RT5880 substrate that was utilized for implementing the microstrip line based feed network. The experimental verifications demonstrated that the FPA exhibited 3.33% $|S11| < -10$dB bandwidth and scanned the beam over $\pm 30^0$ field of view (FoV) with a maximum realized gain of 24.8dB. The microfluidic based FPA's radiation efficiency was also shown to be better than that of its RF switched implementations.

The resonant based feed network of the aforementioned microfluidic FPA has been shown to produce high level of sidelobe and bandwidth reduction. In this paper, we introduce new resonant and non-resonant based feed network layouts that significantly alleviate the issues of sidelobe and bandwidth. Moreover, we demonstrate a new "liquid-metal-free" implementation of the microfluidic FPA by utilizing metalized plates inside the microfluidic channels as the antenna elements. This constitutes a major deviation towards accomplishing non-toxic and more-reliable device implementations. This paper will also demonstrate techniques for extending the concept of 1D microfluidic based FPAs into 2D by using two bi-directional micropump units (i.e. one per major scan direction).