Millimeter Wave Beam Steerable Tiny Lens Antennas Employing 3D Spatial Filter Arrays

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Various types of millimeter wave antennas utilizing enhanced radiation aperture such as cavity, Metasurface and lens structures have long been studied. In the conventional prototypes of such antennas, two common features are found as bottlenecks in commercializing such antennas toward wireless and radar industry.

The first bottleneck is that enhanced aperture efficiency focusing on boresight gain enhancement comes at the expense of decreased beam steerable coverage. Novel techniques to mitigate the degree of the coverage decrease and accurate characterization of a trade-off between gain and beam steerable coverage haven't been investigated well in literature. The aforementioned aperture enhancement techniques can be compared in the aspect of compatibility with electronic beam scanning. Among them, cavity antennas are most vulnerable to beam steering due to inherent operation mechanism replying on multiple reflections. On the other hand, Metasurface and lens transforming the phase of the incoming waves into desired phase fronts are more predictable in terms of difference between desired phase front for desired beam steer angle and actual phase front. The second bottleneck is that such aperture-enhanced antenna systems typically have bulky size in terms of volume as well as area. Efficient design methodologies of tiny aperture antenna systems utilizing 3D configuration needs to be studied for next-generation small wireless and sensing platforms. Recent advancement in PCB-based Metasurface technology enables ultra-thin membrane configuration for spatial filter arrays having the capability in phase transformation. This thin configuration enables low-mass and small-volume 3D topology of aperture antenna systems.

In this paper, a preceding study to demonstrate feasibility of achieving gain enhancement from spatial filter arrays at the distance of less than half of the wavelength from the feed antenna will be first presented. It will be found that prior design procedure for small-aperture 2D flat lens exhibits limits in gain enhancement at such near distance. Next, it will be shown that the membrane lens realized by spatial filter arrays can be applied for tiny antenna volume to achieve an increase in effective aperture size. Finally, a design technique to acquire a moderate angular coverage along the azimuthal axis and corresponding design results will be discussed.