Planar Reflectarray Antennas with Spherical Phase Distribution for Two-Dimensional Beam-Scanning

Payam Nayeri[(1)], Fan Yang[(1, 2)], and Atef Z. Elsherbeni[(1)]

(1) Department of Electrical Engineering
University of Mississippi, University, MS 38677-1848, USA
pnayeri@olemiss.edu, fyang@olemiss.edu, atef@olemiss.edu

(2) Electronic Engineering Department
Tsinghua University, Beijing 100084, China

Microstrip reflectarrays combine the many favorable features of both reflectors and printed arrays, and create a new generation of high-gain antennas which has low-profile and low-mass features. In addition to these mechanical advantages, they are also quite suitable for applications requiring high-gain beam-scanning. On the other hand, radiometer antennas for earth remote sensing or radio astronomy are required to have two-dimensional beam-scanning capability, with high resolution, low loss, and low cross-polarization features; therefore a reflectarray can be a good choice for the beam-scanning antenna in these systems.

Conventionally, the phase distribution on a reflectarray aperture is designed based on the phase compensation of a parabolic reflector. However, for beam-scanning applications these designs show a poor performance. Spherical reflectors on the other hand are quite suitable for wide-angle two-dimensional beam-scanning, and since reflectarray elements can provide any value of phase shift, one can design the reflectarray aperture based on the phase compensation of a comparable spherical reflector.

The goal of this work is to study the feasibility of planar reflectarray antennas with spherical phase distribution for beam-scanning applications. First, analytical expressions are derived for the aperture phase distribution of spherical-phase reflectarrays. In the next stage, the restricted aperture approach is used to design spherical-phase reflectarray antennas, and numerical studies are performed to determine the optimal focal of these planar designs. It is revealed that the optimal focal is a function of the scanned beam direction, and the focal length is reduced as the scan angle increases. In addition the beam-scanning performance of the reflectarrays are compared with spherical reflectors with the same subtended angle, and it is shown that for moderately wide scan coverage, a similar performance can be realized with these planar arrays. Moreover, parametric studies on the taper effect of the illuminated aperture, the size of the corresponding sphere, and the scan range are conducted, to characterize the beam-scanning performance of these antennas. These studies show that planar reflectarrays with spherical phase distribution can be a suitable choice for a beam-scanning radiometer antenna in remote sensing or radio astronomy applications.