The Parabolic-Torus-Phase Reflectarray Antenna

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Since the early 1990's, printed reflectarrays antennas have emerged as the new generation of high-gain antennas, providing many advantageous features such as low-mass, low-profile, and low-cost over reflectors and printed arrays. Moreover, they are also quite suitable for applications requiring high-gain and beam-scanning features. For the beam-scanning operation, one approach is to equip the reflectarray elements with a phase tuning mechanism. Another approach is to move the phase center of the feed antenna, which ultimately changes the phase on the reflectarray aperture, leading to a scanned beam. While each approach has its own advantages, the primary advantage of the later approach is the relatively low cost. The drawback however is that it suffers from poor collimating properties for scanned beams in conventional parabolic-phase reflectarrays.

Similar to parabolic reflectors, the main beam of a parabolic-phase reflectarray can be scanned by displacing the feed antenna; however the scan range is limited to a few beam-widths. On the other hand, the parabolic torus reflector can scan many beamwidths along a circular arc in one angular plane; therefore it is a suitable design for one-dimensional beam-scanning applications. Since in reflectarrays one has direct control over the phase of each element on the aperture, we can enlarge the scan range by designing the array based on the phase compensation of a comparable parabolic torus reflector. In this work, we study the feasibility of designing planar reflectarray antennas with parabolic-torus-phase distribution for one-dimensional beam-scanning. Analytical expressions are first derived for the aperture phase distribution of parabolic-torus-phase reflectarrays (PTPRAs). In the next stage, numerical studies are performed to determine the optimal focal of these planar designs. It is shown that similar to spherical-phase reflectarrays, the optimal focal path of these planar designs is different than the corresponding reflector, and moves closer to the aperture surface as the scan angle increases. Moreover, comparative studies between the scan performance of parabolic torus reflectors and the proposed design reveals that the PTPRA can achieve a similar performance for moderately wide scan coverage, with the advantage of having a low-profile planar aperture, which makes it a suitable choice for high-gain beam-scanning applications.