Reflectarray Antennas for Plane Wave Generation in the Near-Field

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Planar microstrip reflectarray antennas combine the many favorable features of reflector antennas and antenna arrays, and create a hybrid design which has shown a momentous promise as the new generation of high-gain antennas. The flat surface of the reflectarray antenna consists of phase changing elements, which create the collimated beam. With the rapid advancement of printed circuit technology, reflectarray antennas can offer a low profile, low mass, and low cost solution for high-gain antennas. On the other hand, measuring far-field antenna patterns requires separating the transmit antenna and the antenna under test (AUT) by a large distance in order to minimize the field amplitude and phase variations across the test aperture. However, when the AUT is electrically large, the far-field distance becomes quite large, and techniques such as compact range, near-field scanning and antenna focusing are necessary. These approaches allow for accurate prediction of the far-field pattern even though the measurements are taken in the near-field.

Antenna arrays can be used to generate a plane wave in the near-field and both theoretical and experimental results have been presented for a variety of configurations over the years. In most cases an optimization method is required in order to synthesize the array for near-field operation. Owing to their unique hybrid capabilities, reflectarrays can be a good solution for a low mass and low cost system, however a number of challenges exist here. First, the amplitude of reflectarray elements is fixed by their position on the aperture and the feed properties, hence one only has control over the element phase. Second, a global search is quite challenging for reflectarrays due to the large number of elements. The key to effective implementation of such a design is to derive a closed form analytical solution to the near electric fields radiated by the reflectarray antenna which can then be used to synthesize the phase of reflectarray elements through numerical optimization. In this work, the mathematical expressions for electric fields are obtained using a modification of the array theory analysis technique reported in P. Nayeri et al., IEEE Antennas and Propagation Magazine, vol. 55, pp. 127-134, 2013.

To demonstrate the feasibility of this approach, a prime-focus Ka-band reflectarray with a circular aperture diameter of 15λ and 648 elements is studied for plane wave generation in the near-field. The feed antenna which has a $q = 6.5$ based on the cos q radiation model is placed at a distance of 12.5λ from the center of the aperture. The system is designed to generate a plane wave in a 5λ×5λ region at a distance of 20λ from the reflectarray aperture. Particle Swarm Optimization (PSO) is used to optimize the phase of the reflectarray elements with a fitness function that minimizes both phase and magnitude variations of the electric fields in the desired plane wave region. The optimized reflectarray antenna achieved a maximum field amplitude variation less than 0.85 dB and a maximum phase variation less than 34º in the desired region. It is important to note that in this study, feed blockage is ignored, however in practice it is necessary to implement an offset configuration. Further discussion on the offset system, some practical considerations on the size and distance of the plane wave region, as well as simulation results will be presented at the time of the meeting.