A Method for Achieving 2-Bit Phase Quantization for Reconfigurable Reflectarray Antennas Having Single Radiating Layers

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One-bit phase quantization is widely used in electronically reconfigurable, beam-collimating reflectarrays due to reduced complexity and low cost. It has been shown that the use of 1-bit phase correction results in a gain reduction of about 3.2 dB compared to the case where the array has continuous phase correction. Increasing the number of phase states for the array elements from two (1 bit) to four (2 bits) helps recover about 2.5 dB of this 3.2 dB gain reduction and significantly decreases the side-lobe levels. However, further increasing the number of bits for phase quantization beyond two yields little improvement in beam collimation and can introduce higher losses from the larger numbers of switching elements and higher complexity for the control circuitries. Therefore, reconfigurable arrays using 2-bit phase quantization represent a good compromise between cost and performance. In this work, we present a novel method for acquiring 2-bit phase quantization for reconfigurable reflectarray antennas having a single radiating layer.

The proposed principle for achieving 2-bit phase quantization is to exploit four distinctive reflection modes of array elements. Specifically, in a reflectarray consisting of dipole-type radiating elements, the array can be reconfigured to achieve four different states using four different PIN-diode switches. We illustrate the proposed 2-bit phase quantization via a proof-of-concept reconfigurable unit cell design. The unit cell consisted of three metallic layers: a top layer with dipole elements, a ground plane located below the dipoles, and a bottom layer behind the ground plane where the switching is implemented. The dipole elements were connected to switches located on the back side of the ground plane using through substrate metalized vias. In this implementation, the connections were hard wired on the back side of the ground plane, but they are expected to be replaced by PIN diodes in a fully electronically reconfigurable version. Each of the four reflection modes were activated by setting a specific combination of ON and OFF states of the four switches. Each static unit cell, with a periodicity of 12 mm and total thickness of 2.5 mm, was implemented using three layers of Rogers RO4003C bonded together by two layers of 0.1-mm thick Rogers RO4450F prepegs. Simulation results produced in CST Microwave Studio predict that the unit cells should provide reflection coefficients > -1 dB and reflection phases $\leq \pm 15°$ around the corresponding desired phase values in all modes of operation over 9.5-11 GHz. We plan to use the proposed unit cells to construct several static reflectarray antennas with aperture diameters of 30 cm and focal lengths of 25 cm to investigate the beam scanning and bandwidth performance of the beam-steerable reflectarray. Further simulation results and experimental characterization for the static reflectarray prototypes will be presented and discussed at the conference.