A PLANE-WAVE BEAM-STEERING LENS DESIGN USING MICROSTRIP SWITCHED-LINE PHASE SHIFTERS


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Abstract

A compact beam-steering lens design appropriate for millimeter-wave and submillimeter-wave applications is experimentally verified with an X-band test model. The lens achieves coupling to plane-wave beams through arrays of patch antennas placed on its two outer surfaces. The isolation between input and output antennas is accomplished by inserting a metal ground plane in the middle of the lens. The two closest patch antennas on the front and the backside are connected together with microstrip circuits that include switched-line phased shifters and interconnecting vias through the lens substrate. Three different X-band 100-element plane-wave microstrip lenses that use passive delay lines instead of actual phase-shifters were fabricated to successfully demonstrate the beam-steering angles of 20 and 40 degrees. From a separate waveguide measurement on the unit-cell element only, the insertion loss of the lens was estimated to be approximately 3.5 dB with bandwidth of 2% at 10 GHz.

Key Words: beam-steering lens, patch antenna, phase shifter

1. Introduction

Quasi-optical space-fed antennas provide a solution for implementing high-power components appropriate for millimeter-wave and sub-millimeter wave systems with their
simplicity and low-loss performances [1]. Many such antenna arrays including solid state amplifiers [2] have been introduced. Similar techniques have also been adopted to build phased array antennas for controlling the direction of propagating microwave beams. Phase array antennas steering the transmitted beam through the lens rather than changing the direction of the reflected wave are more attractive because they provide easier integration in lens waveguide systems [3]. Several published examples of quasi-optical beam-steering lens designs include a ferroelectric lens [4] and a beam-steering grid using discrete PIN-diode switch arrays [5]. Both circuits possess a broad frequency bandwidth and relatively simple dc-bias schemes, and more importantly, they maintain the plane-wave mode traveling through the lens. The published data for the ferroelectric lens shows a low insertion loss of less than 1 dB at X-band. However, the required dc bias voltage to control the permittivity of the lens could reach up to 10kV, and extra matching layers are necessary to remove the mismatch loss from lens surfaces. The beam-steering grid design is very simple and well-suited for the possible use of MEMS RF switches [6]. The major difficulty with this design lies in the circuit fabrication as