

2-bit Dual-Polarized Reconfigurable Reflectarray for High Power Microwave Communications

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Abstract—A 2-bit dual-polarized reconfigurable reflectarray comprised of an all-metal cross-dipole unit cell is presented for high power microwave (HPM) applications. The reflectarray unit cell is comprised of a pair of orthogonal bowtie dipoles. Each of the four arms are connected to a 2-bit phase shifter in the back end. The uniqueness of this design is use of inductive metal posts at the dipole edges to support the dipole above the ground plane and achieve reflective resonance. This reflectarray is designed to withstand high radiation intensity from a high-power feed and then guide this power towards directed beam. Adjusting the delay line lengths connected to each dipole provides full phase shift control across 0° to 360° . Simulations showed that the reflectarray achieves high gain. Specifically, the unit cell gain is 5 to 6 dBi at the operating frequencies.

Keywords—High Power Microwave, Reconfigurable, Reflectarray, Directed Energy, Phase Shifter.

I. INTRODUCTION

There is a strong need for high-power wireless charging and beamforming. However, these high-power systems often rely on mechanical moving parts to steer their beams [1], leading to slower operation and bulky designs. With this in mind, in this paper, we present a high-power reflectarray aperture designed to be adaptable and integrated with autonomous system. This proposed high-power microwave (HPM) aperture enables high-speed electronic beam steering.

A recent demonstration [1] of an all-metal antenna for High-Power Microwave (HPM) systems employed mechanically moving components to achieve phase shifting across 0° to 360° . This design's reliance on mechanical movements resulted in slower operation and a bulky profile. In another recent paper [2], a reflectarray was proposed for HPM applications using rotating metal elements. These were fixed to a supporting rod for phase control. By contrast, the proposed design uses gallium nitride (GaN) semiconductor switches for reconfiguration to achieve 2-bit phase shifting.

A reflectarray element connected to different delay lines reflects radio waves at varying phases [3]. In this paper, we propose an all-aluminum reflectarray that employs 4-port unit cell as shown in Fig. 1. Each antenna element uses four switches to choose one of the switchable delay lines at the termination of each element. This enables beamforming and realizes a 4-bit phase shifter. Because the switches are shielded, this approach increases the periodic element's maximum power handling capacity as much as four times.

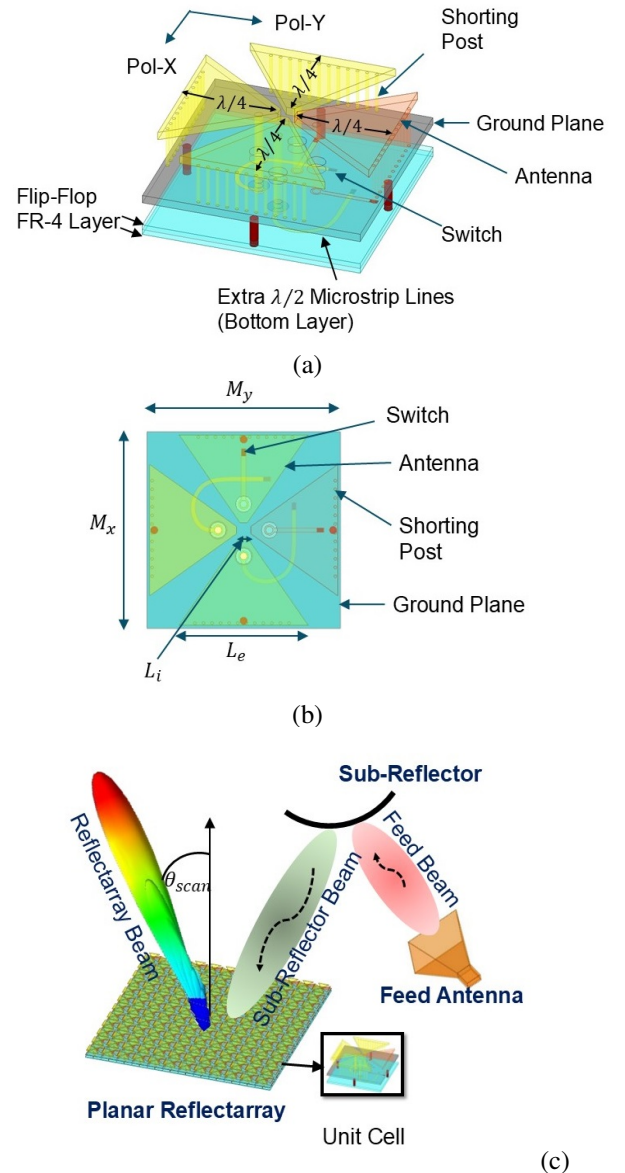


Fig. 1. Reconfigurable dual-polarized reflectarray and unit cell details: (a) 3D view of the 4-port reflectarray antenna unit cell, (b) top view of the unit cell antenna element, (c) reflectarray set-up using a sub-reflector,.

II. UNIT CELL DESIGN: HIGH-POWER RECONFIGURABLE REFLECTARRAY

The unit cell of the proposed HPM reflectarray in Fig. 1 is comprised of an all-aluminum cross-dipole and has inductive posts at the edges. These inductive posts are parallel to the antenna input to lower the input impedance. The main reason for using these metal posts is to avoid using a dielectric layer between the antenna and the ground plane. The unit-cell features cross-dipoles fabricated from 5-mm-thick aluminum, placed over a 5-mm-thick ground plane at 18mm height. Twelve metal posts, each with a diameter of 2mm and a length of 18mm, are positioned at the edges of the dipole. Subsequently, four input pins with a diameter of 5mm pass through four 11mm diameter holes in the ground plane to reach the phase-shifting layer. As illustrated in Fig. 1a, this design incorporates two flip-flop layers with an in-between common ground plane to accommodate all the delay lines and switches connected to the four input pins. The flip-flop dielectric phase-shifting layers consist of a 3.2 mm FR-4 substrate (dielectric constant, $\epsilon_r = 4.2$) with 70 μm thick copper traces. Fig. 1b presents the top view of the antenna element, with its geometric dimensions detailed in Table I. Fig. 1c shows the complete HPM reflectarray setup including a Cassegrain subreflector and feed antenna.

III. ARRAY SIMULATION AND RESULTS

The proposed HPM antenna element was simulated as unit cell under periodic boundary conditions (PBC) in Ansys HFSS. The antenna element and its phase shifters exhibit reflective behavior as shown in Fig. 2a, with reflection efficiency ranging from 80% to 99% for both polarizations and various delay line lengths, except for a narrow absorption band in center. Fig. 2b depicts that a 72 mm delay line variation results in a symmetric 360° phase shift in reflection. Also, as shown in Fig. 2c, the HPM antenna element provides a gain of 5 dBi at 1.1 GHz (after reflection) for both polarizations.

TABLE I
REFLECTARRAY UNIT CELL DIMENSIONS

Parameters	Dimensions (cm)	Parameters	Dimensions (cm)
M_x	13.2	L_i	1.6
M_y	13.2	L_e	8.8

IV. CONCLUSION

An all-metal high-power microwave (HPM) reflectarray element is designed for directed energy applications. Here, we introduced rapid electronic steering using splitting power into four high-power GaN switches. This design incorporates 5 mm thick aluminum plates on the antenna and ground layers, providing protection for the phase-shifting layer against intense radiation. A 12×12 reflectarray prototype will be built to steer the beam and test the design.

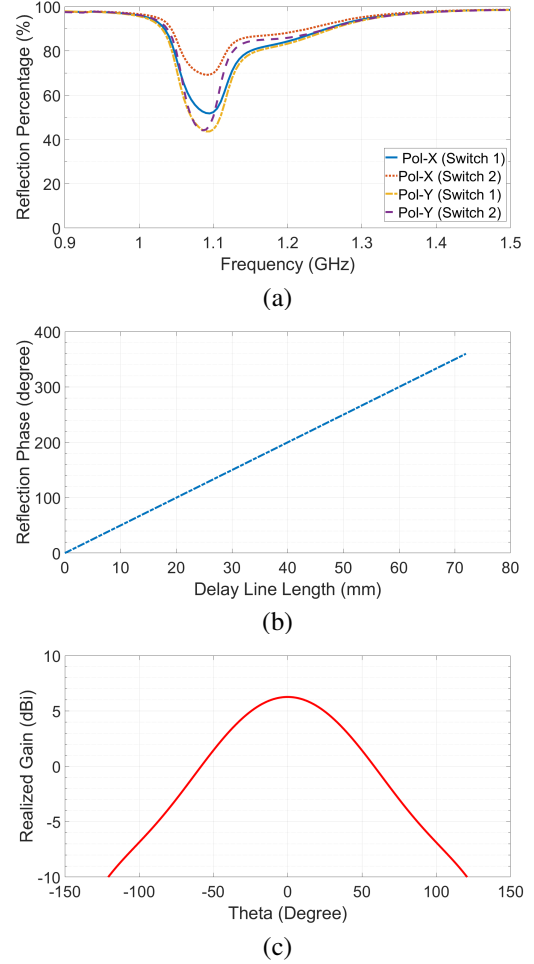


Fig. 2. Reflectarray unit cell performance via simulations: (a) percent signal reflection vs frequency, (b) phase variation vs delay line length, (c) unit cell realized gain (dBi) vs frequency.

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