Dual-Band Dual-Sense Polarized Metasurface Antenna with Two-Dimensional Beam Steering Using Surrogate Hinges Origami Reflectors

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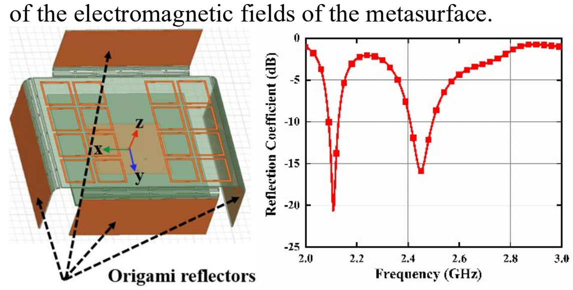
Abstract: A metasurface-based dual-band, dual-sense polarized two-dimensional beam-steering antenna is proposed in this study. The antenna consists of a rectangular probe-fed source antenna, with a metasurface integrated with four surrogate hinges based origami reflectors positioned on top. The origami reflectors can be folded/unfolded to achieve two-dimensional beam steering. The antenna can radiate broadside beams (Mode I), or beams steered by ±30° in the yz plane (Mode II and III) at the lower band resonant frequency of 2.1 GHz. At the upper band resonant frequency of 2.4 GHz, the antenna can radiate beams steered by ±20° (Mode IV and V). The proposed antenna shows promising performance for applications requiring dual-band, dual-sense polarization, and two-dimensional beam steering.

I. INTRODUCTION

Researchers have explored many ways to make metasurfaces reconfigurable for beam steering. One popular approach is to use electrical components like PIN diodes and varactor diodes. However, these methods have drawbacks such as poor isolation, limited power handling, high cost, and complex biasing networks [1]. Origami is a promising new technique for reconfigurable metasurfaces. It is the art of folding any geometry into complex 3D shapes, and it is found in nature, in the wings of insects, leaves, and even embryonic intestines. In this study, we propose a new way to tune the electromagnetic wavefront of a metasurface using origami reflectors. These reflectors are made of surrogate hinges, which are small flaps of copper tape attached on 3D printed substrate that can be folded and unfolded.

II. ANTENNA DESIGN AND PERFORMANCES

The antenna presented in this study consists of a probe-fed patch antenna designed on Rogers RT duroid 5880 with thicknesses of 1.57 mm and a metasurface, which is designed on 3D printed PLA substrates having thickness of 1.5 mm. Four origami reflectors are attached to the metasurface to achieve beam steering capability. These reflectors can be folded and unfolded using surrogate hinges, as shown in Figure 1. A thorough evaluation of the antenna's performance is conducted via an extensive full-wave simulation, utilizing the ANSYS High-Frequency Structure Simulator (HFSS). Figure 2 shows, the simulated 3D radiation patterns, which demonstrates that the antenna can achieve beam steering of ±30° in the xz plane at the lower band resonant frequency of 2.1 GHz working in TM01 mode and beam steering of ±20° in the yz plane for the upper band resonant frequency of 2.4 GHz working in TM10 mode. To enable continuous beam steering capability, actuators will be incorporated with each origami reflector. These actuators will control the folding and unfolding of the reflectors, allowing for precise manipulation of the electromagnetic fields of the metasurface.



(a) (b)

Figure 1: (a) Metasurface based beam steering antenna with surrogate hinges and origami reflectors (b) Simulated S-parameter.

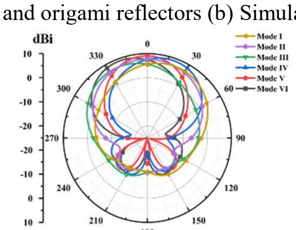


Figure 2: Simulated 2-D radiation patterns of the proposed antenna in all modes.

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