A Thick Origami Traveling Wave Antenna

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***Abstract*—This paper presents a thick origami foldable traveling wave antenna. A typical microstrip rampart-line antenna is appropriately modified to enable folding/unfolding capability using a surrogate hinge. This antenna is designed on a 1.5 mm-thick FR4 substrate circularly polarized at 3.4 GHz and exhibits a peak gain of approximately 2.85 dB at broadside.**

***Index Terms*—antenna, circular polarization, hinge, thick origami, travelling wave antenna.**

I. Introduction

The concept of physically reconfigurable antennas has been recently introduced with origami antennas e.g., [1], [2]. Specifically, origami antennas can transform 2D structures into a 3D ones with a prescribed way. This capability has been extensively used in numerous applications, where efficiently packing and easy deployment are needed, [3]. Also, origami antennas have used the shape deformation of origami designs to provide several reconfigurable characteristics, [4], [5]. Recently the first thick origami array was introduced in [6]. This array was a monolithic design (i.e., the antenna and its hinges were fabricated using one PCB), which also exhibited better performance compared to the corresponding design. Here, we propose the first thick origami travelling wave antenna based on a microstrip-line array.

Circularly polarized microstrip arrays are extensively used in communication, remote sensing, navigation and radar systems because of their low-profile. They are classified into three main categories: a) circularly polarized microstrip patches, b) composite elements of electric and magnetic current source elements, c) traveling wave arrays that utilize radiation due to suitable discontinuities in traveling wave transmission lines. Here, we use the third type of array and a hinge that allows the array to fold/unfold while maintaining its electromagnetic characteristics.

II. Antenna Design

A. Circularly Polarized Microstrip Array Unit Cell

A circularly polarized $4x1$ microstrip line array is designed. Fig. 1 shows the unit cell used for the microstrip array initially proposed by Hall, [7]. The unit cell is composed of four right-angle bends as well as three lengths represented as $a = 3/8\lambda_g$, $b = 1/2\lambda_g$, and $c = 1/4\lambda_g$. When these lengths are appropriately chosen with respect to the guiding frequency, the radiated fields from the four right angle bends produce circular polarization. At the four right angle bends, miters are introduced in order to mitigate the susceptance resulting from these discontinuities. To make the array foldable a surrogate hinge (Fig. 2) is introduced between the two middle elements (Fig. 3).

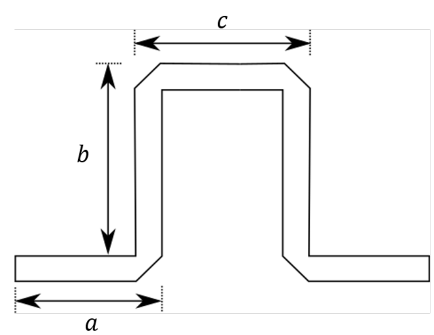

Fig. 1: Array unit cell.

B. Surrogate Hinge

The hinge used in this work was originally proposed by De Figueiredo, [8]. Shown in Fig. 2, the hinge allows the array to bend in either the clockwise or counter-clockwise direction minimizing the stress on the antenna components. A main advantage of this type of hinge is that both the array conductive layout and the hinge can be fabricated using a milling machine and a single PCB. Thus, a monolithic design can be fabricated without the need of any additional manufacturing processes. Results showing the impact of bending the hinge will be shown at the conference.

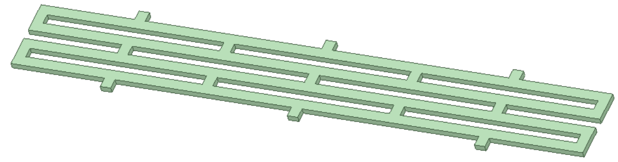

Fig. 2: Surrogate hinge.

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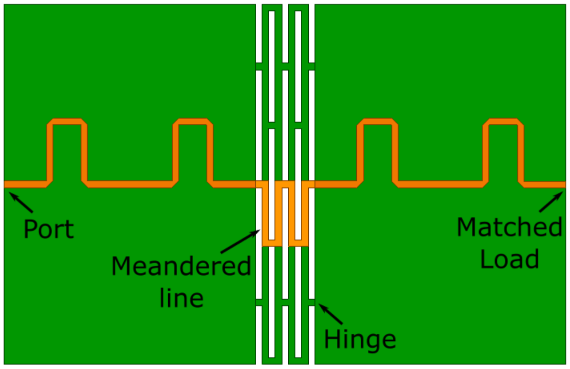

Fig. 3: 4×1 Traveling wave antenna.

C. Final Structure

The final design, shown in Fig. 3, encompasses the electromagnetic properties of the microstrip array and the flexibility of the hinge, all on a single PCB. The 4-element array is separated along the center of the array and is placed on the two opposing sides of the hinge. The array is then connected together with the use of a meandered line, which is guided along the length of the hinge. Both electromagnetic and mechanical analyses are performed for the optimal incorporation of the hinge. The corresponding results are not presented here for brevity and they will be presented at the conference.

III. Results

Fig. 4 shows the gain of the microstrip array with and without the hinge employed. It can be seen that the array without the hinge has a slightly wider beam, and also the level of its side lobes is significantly lower. This is expected since both dielectric and ground plane have been removed due to the introduction of the hinge. However, the array with the hinge radiates at the desired frequency of 3.5 GHz, with a maximum gain of approximately 2.8 dB. Both arrays with and without the hinge are circularly polarized. As shown in Fig. 5 the proposed design shows an axial ratio $\leq$ 3 dB at a wider bandwidth (3.19 GHz - 3.54 GHz) compared to the design without the hinge (3.09 GHz - 3.34 GHz). The shift of the circularly polarized bandwidth can be also attributed to the modifications done on the hinge portion of the design.

IV. Conclusion

A thick origami traveling wave antenna with a hinge is presented. The proposed design performs equivalently to the standard non-origami design. Also, more sections can be easily added in this configuration thereby creating a foldable array that can be stowed in an area as large as its unit cell. This provides significant savings in the antenna volume needed to stow this antenna.

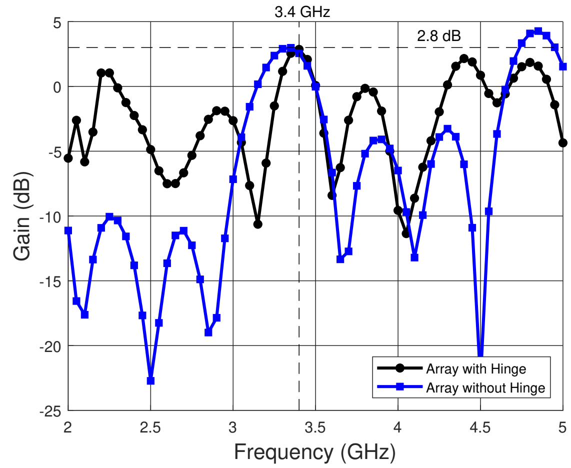

Fig. 4: Gain vs frequency.

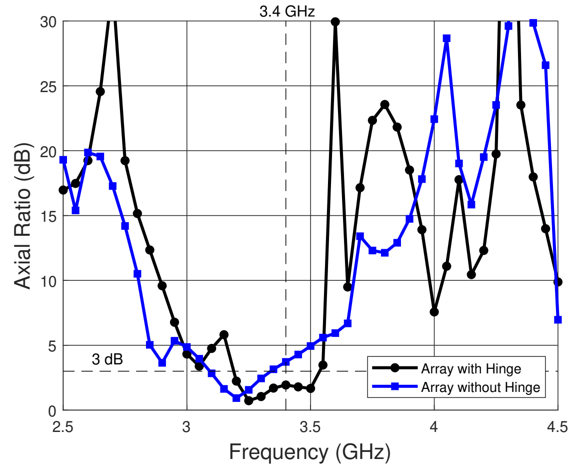

Fig. 5: Axial ratio vs frequency.

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