A Novel Reconfigurable Origami Spring Antenna

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***Abstract*—A foldable origami spring structure is presented in this paper, which can be expanded and collapsed. Based on this structure, one origami antenna is designed with operating frequency that can be changed based on its height. The return loss, far-field radiation pattern and peak gain of this antenna are presented.**

I. INTRODUCTION

Reconfigurable antennas are very attractive recently, because they have unique advantages over standard antennas, such as, multi-functionality and multi-band operation. Collapsible antennas are also very useful as they can be folded to save space. Many complex geometrical designs have also been used in electromagnetics to develop components with enhanced performance and unique capabilities. In [1], a tape spring antenna is proposed, which can work in both deployable and stowed states. This antenna as it deploys along the tape line, it can only be designed as dipole or monopole. In [2], a tunable helical antenna is presented, which uses a shape memory alloy placed in parallel with the antenna to control the antenna height. But it's hard to make the spring antenna structure have a rigid geometry.

In this paper, an origami structure is proposed, and it is folded by dielectric material such as paper. When pressure is exerted on the top of this spring structure, it collapses, and it can deploy when pressure is removed. We designed a novel 3D origami antenna based on this origami spring structure, which can be folded and unfolded to different heights thereby proving reconfigurable performance in terms of frequency of operation and gain in order to support different services.

II. ORIGAMI SPRING STRUCTURE

Fig. 1 shows a piece of creased flat paper. The solid lines are valley-folds. The long dimension of the paper is folded into 4ths, and the short dimension is folded into 12ths. After the folding, we have 48 small rectangles. Then fold each rectangle diagonally in half along the dash lines, which are mountain-folds. The paper will now be rolled and twisted until it forms the collapsible spring as shown in Fig. 2. We can see there are 4 levels of this spring structure, and each level is formed by 12 twisted rectangles.

Fig. 3 shows we can print metal layers on the paper base, and input excitation from one side of the conductor. There will be a 3-D origami antenna after the paper is folded. Therefore, we can make different metal structures by attaching different metal shapes on the paper.

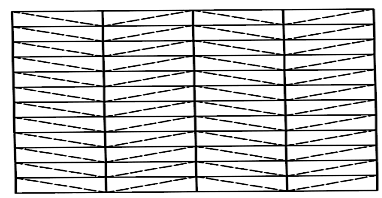

Fig. 1. Creased paper for folding origami spring.

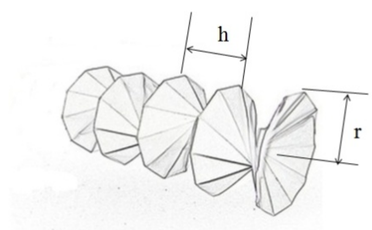

Fig. 2. Origami spring paper structure.

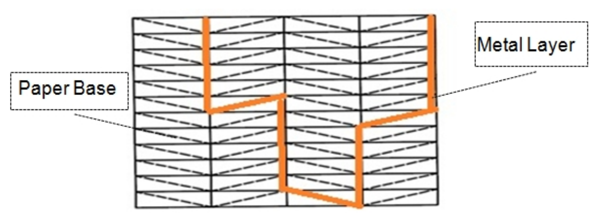

Fig. 3. Metal layers on the paper base

III. SIMULATION OF ORIGAMI SPRING ANTENNA

Fig. 4 shows the spring antenna we designed in ANSYS HFSS. It is built on a paper base, which has 12 rectangles along the short dimension and 4 rectangles along the long dimension. The length of every small rectangle is 20 mm, and the width is 10 mm. We used a copper tape along the edge of first level, after crossing 6 rectangles. The tape goes along a diagonal to the position which lies opposite on the edge of the second level. Repeat this process until the 4-levels of the antenna are finished. The width of the copper tape is 5 mm, and the thickness is 0.1 mm. This model is fed by 50-Ohm coaxial probe.

The radius *r* of every level, which is the distance between the central axis and the edge, is related to the height *h* of the

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level as shown in Fig. 2. The bigger *h* is, the smaller *r* is. The height of the whole antenna changes from 20 mm to 120 mm from the collapsing state to the expanding state. The height of this antenna's unfolded state is 100 mm, and the height of its folded state is 40 mm.

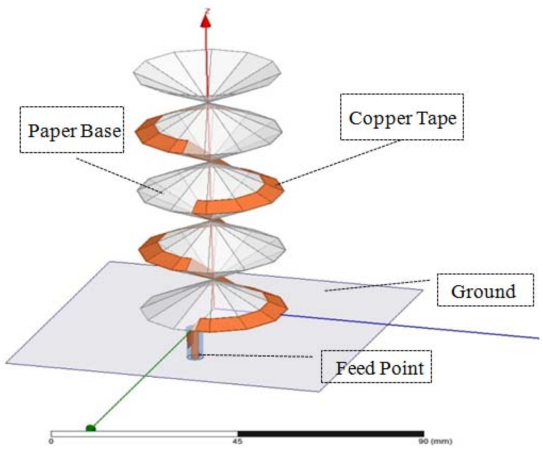

Fig. 4. Origami spring antenna in HFSS.

The graph in Fig. 5 shows the simulated return loss of this antenna at different states. From the simulation results, we can find that the two S11 curves have similar distribution of resonant frequencies. The folded antenna has a better S11 at 2560 MHz, and the unfolded antenna has a better S11 at 2190 MHz. Fig. 5 shows that the resonances of this origami antenna change when it folds or unfolds thereby providing a reconfigurable performance.

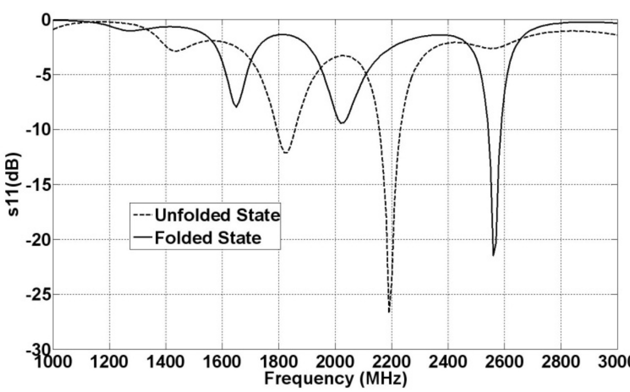

Fig. 5. Return loss for unfolded and folded states.

Fig. 6 shows the far-field realized gain pattern of this antenna at the resonant frequencies for different heights. It can be seen that this antenna is directional, and the peak gain is along the z direction. Fig. 7 shows the simulated realized gain along the z direction of the origami spring antenna versus frequency at different states. It can be seen from the black circle marker in Fig. 7 that the unfolded state has significantly larger realized gain at 2190 MHz and 1820 MHz. However, at 2560 MHz, the folded state achieves a larger realized gain. Therefore, this illustrates again that this origami antenna is a spatially reconfigurable antenna that based on its height provides optimal gain at different frequencies. In the conference, measurements of this design will be also presented.

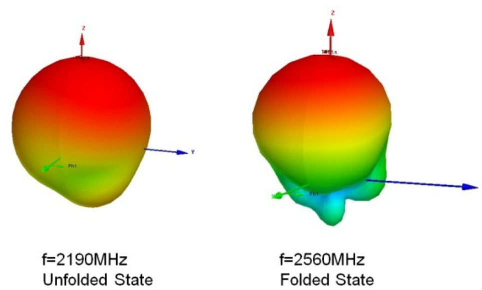

Fig. 6. Radiation pattern for unfolded and folded states.

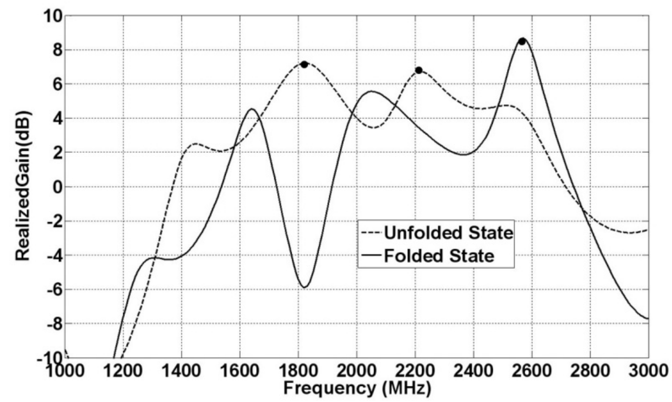

Fig. 7. Realized gain for unfolded and folded states.

IV. CONCLUSION

An origami spring structure is proposed in this paper. Based on the structure, one origami antenna is designed. The height of the spring antenna can be easily and precisely controlled by pressing the spring base. The simulation results of the return loss and realized gain showed that the working frequency of this antenna changed by its height.

REFERENCES

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