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Pop-Up Card Inspired, 3D-Printed Corner Reflector Antenna—A Novel Deployable Antenna

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***Abstract*—This paper presents a pop-up card inspired corner reflector antenna, fabricated using inkjet and 3D printing technologies. The reflector is designed with a state-of-the-art folding structure that has an integrated fold limiting mechanism, which accurately sets the flare angle to a predefined position. As a result, the antenna can be easily deployed and stored compactly. The antenna resonates at 6.4 GHz, with a percentage bandwidth of 7.34% and a maximum realized gain of 14 dBi at resonance frequency.**

I. Introduction

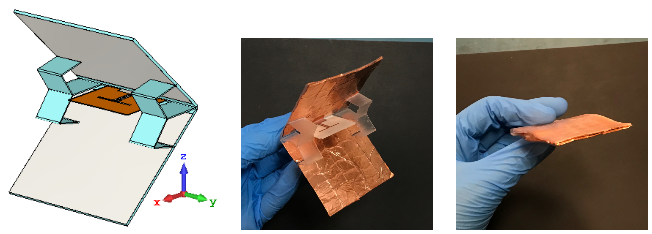
Antennas play a critical role in wireless communications, allowing for long-distance signal transmission with minimal losses. While the addition of a reflector to an antenna increases gain and control over radiation patterns [1], a reflector is a 3D element that is heavy and cannot be easily stowed, limiting its application in mobile communications. To address the issue of size, a foldable antenna can be used. Previously investigated deployable and foldable antenna used a paper substrate, which is not durable or waterproof [2].

A deployable antenna can also be reconfigurable, providing additional capabilities. The effect of flare angle on beamwidth is discussed in [3]. Selectively energized plasma [4] and reconfigurable frequency selective surfaces [5], [6] have also been used to realize reconfigurability. However, these methods change the electrical properties of the antenna without altering its shape, making the antenna complex and not deployable.

In this paper, we present a pop-up card inspired, deployable corner reflector antenna. The proposed reflector features a simple design that seamlessly folds to occupy a smaller volume, making it attractive in various terrestrial and outer-space applications.

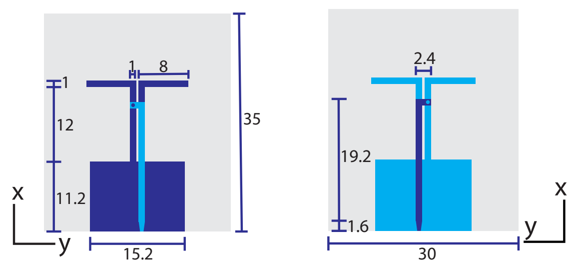
II. Design and Fabrication

The proposed corner reflector antenna, shown in Fig. 1, is composed of a 3D printed, flexible, deployable reflector and an inkjet-printed dipole antenna, with a resonance centered around 6.4 GHz. The dipole was fabricated on 0.3 mm thick RO4003C substrate ($\epsilon_r = 3.55$) with 0.35 mm copper on each side. The antenna fabrication process involves first masking the antenna structure using an inkjet-printed SU-8 mask, and then placing the sample into a ferrous chloride ($FeCl_2$) solution to removed unwanted copper.



(a) (b) (c)

Fig. 1. (a) 3D model of the proposed antenna. Fabricated antenna when (b) deployed and (c) folded.



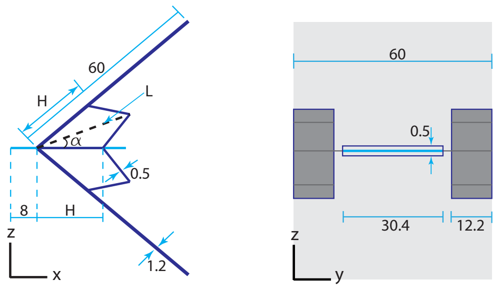
(a) (b)

Fig. 2. Dipole antenna: (a) top (b) bottom. All measurements are in mm.

The proposed dipole antenna, with an integrated balun consisting of microstrip to slot-line feeding structure, is shown in Fig. 2. The double-sided antenna has a dipole, feed arms, and ground plane on the front side (Fig. 2a). The balun was added to the reverse side to balance the dipole feed, with a 0.6 mm via that connects the two sides (Fig. 2b).

The novel reflector was 3D printed as a single unit using a flexible resin, Flexible80A ($\epsilon_r = 2.9, \tan\delta = 0.042$), with a FormLabs Form3 sterolithography (SLA) printer. This material facilitates easy folding and unfolding of the reflector. 3D printing allows the reflector to be quickly and easily fabricated. It also allows for reliable fabrication of identical samples, making the results easier to reproduce.

The fold limiting structure comprises four identical triangles, as shown in Fig. 3a, which is necessary for flat folding of the reflector. These triangles are defined by two side lengths and the angle between them: support height H, peak distance L, and angle α. Angle α is always one-fourth of the flare



(a) (b)

Fig. 3. Reflector: (a) side, (b) front. The flare angle of 80° is 4x the 20° angle in the four identical triangles. All measurements are in mm.

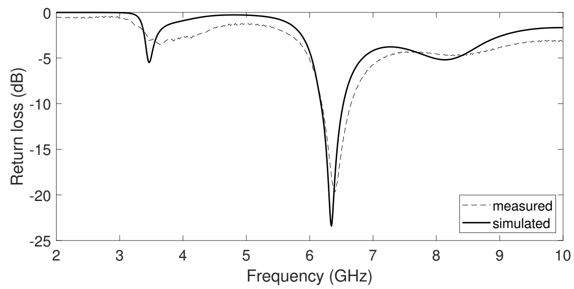


Fig. 4. Simulated and measured return loss vs. frequency.

angle, and because the flare angle is 80°, $\alpha = 20°$. The support height, H, was optimized to 20 mm, which ensures that the reflector panels are sufficiently supported. Peak distance L is defined as the distance from the reflector crease to the fold limiting structure peak. To ensure proper folding, $L > H$, and therefore a distance of 30 mm was chosen. The reflector thickness is 1.2 mm, which is enough to provide sturdiness to the reflector panels. The fold limiting structure is optimized at 0.5 mm for ease of folding.

III. Results and Discussion

The corner reflector antenna was designed and simulated in CST Microwave Studio. The measured and simulated results were found to closely match. Fig. 4 shows the simulated and measured return loss of the proposed corner reflector antenna, with a measured resonance around 6.4 GHz and percentage bandwidth of 7.34%. In simulation, the resonance was around 6.35 GHz and the percentage bandwidth was 5.51%. The realized gain, shown in Fig. 5, has an overall increase from 2–6 GHz, leveling off for frequencies between 6–10 GHz. The measured and simulated realized gain at resonance frequency is 14 dBi and 11.75 dBi respectively. The normalized radiation patterns for the antenna are shown in Fig. 6.

IV. Conclusion

This paper presents a one-of-a-kind, pop-up card inspired corner reflector antenna. The 3D and inkjet printing technologies used to fabricate the antenna are relatively low-cost and are available in academic and commercial labs. Additionally, the flexible material used to fabricate the antenna opens the

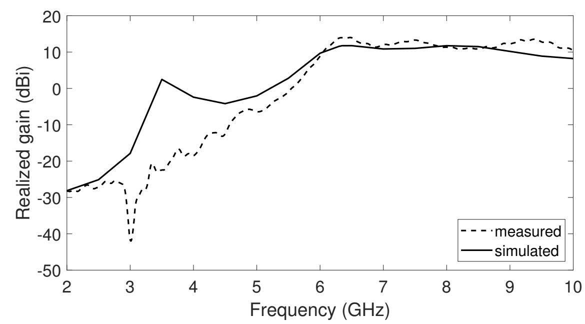
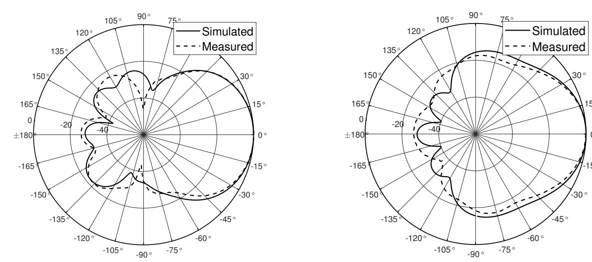


Fig. 5. Simulated and measured realized gain vs. frequency



(a) (b)

Fig. 6. Normalized radiation patterns at 6.35 GHz: (a) E-plane, (b) H-plane.

potential for research on the properties of the antenna in different configurations. The antenna can be folded when needed, improving the portability and minimizing the design profile of the antenna, and making it an attractive design for mobile and satellite applications.

Acknowledgement

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