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A Novel, FSS-Enhanced, Pop-Up Card Inspired Corner Reflector Antenna

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***Abstract*—This paper presents a corner reflector antenna with a reconfigurable radiation pattern. The the corner reflector uses a frequency-selective surface (FSS) as has a variable folding angle. The inclusion of the FSS in the reflector design causes nulls to appear 73° from the direction of maximum radiation on both sides. As the folding angle is decreased from 90° to 60°, these nulls deepen, and the difference between the gain at the nulls and the maximum gain increases. The cause of this may be that the FSS is better at reflecting radiation at the resonant frequency than a solid metal reflector.**

I. INTRODUCTION

The addition of a simple corner reflector can significantly improve the performance of an antenna in many ways, offering an increased gain and narrower beamwidth. Corner reflectors can be used as passive targets for radar and in communications, such as television receivers [1]. Their high directivity also makes them desirable base station antenna [2].

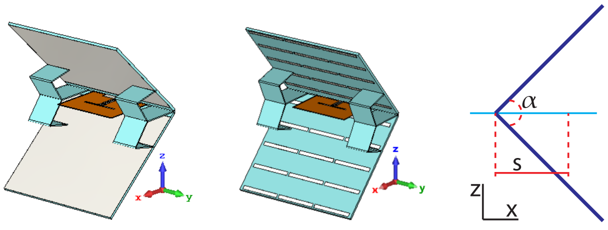
A frequency-selective surface (FSS) generally consists of conductive elements forming a pattern on a surface. This pattern has a certain periodicity and is tuned to one or more desired resonant frequencies. When an electromagnetic wave is incident on this surface, it either passes through or is reflected, depending on its frequency. In this way, a surface can selectively reflect or transmit an electromagnetic wave [3].

Reconfigurable electronics are useful because they can be adjusted in real time to meet the changing requirements of a system connected to them. For example, reconfiguration allows an origami-inspired helical antenna and reflector to operate in different frequency bands [4]. Another example is a reconfigurable FSS that can alter the frequencies reflected off of it [5].

In this paper, we present a corner reflector antenna that uses an FSS as a reflector. By altering the folding angle of the reflector, the radiation pattern is reconfigured, and forms nulls 73° from the direction of maximum radiation at sufficiently small folding angles and dipole-reflector vertex distances.

II. ADDING A FREQUENCY-SELECTIVE SURFACE

Benefits of the initial design for a 3D-printed, foldable corner reflector antenna are that the structure is flexible, reconfigurable, of low cost and weight, and easy to fabricate. A detailed description of the design, shown in Fig. 1a, is given in [6]. However, this structure exhibits a sharp, undesired resonance around 3 GHz. Furthermore, the effect of changes to the reflector angle was not sufficiently investigated during the initial investigation.



(a) (b) (c)

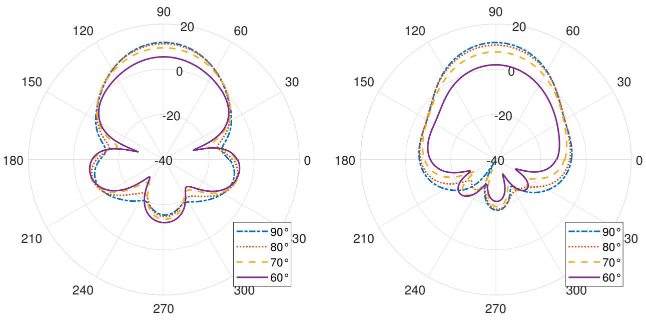
Fig. 1. A 3D simulation model of the proposed antenna in CST Microwave Studio with (a) a solid metal reflector [6] and (b) an FSS as a reflector. (c) Side view showing reflector angle, α, and distance from vertex to dipole, s.

To suppress the lower frequency, the solid metal reflector surface was replaced with an FSS, as in Fig. 1b. This passive FSS was tuned to 6.35 GHz, which should completely reflect waves near the resonant frequency of 6.35 GHz, but not at 3 GHz [3]. In addition, the dipole itself was optimized to further minimize undesired resonant frequencies.

Previous work suggests that doing this could narrow the half-power beamwidth, improve the front-to-back ratio, improve the impedance bandwidth, and increase gain [2][7]. Another potential benefit is that if the FSS was backed by a transparent substrate, it could provide RF blocking without inhibiting optical transparency [8].

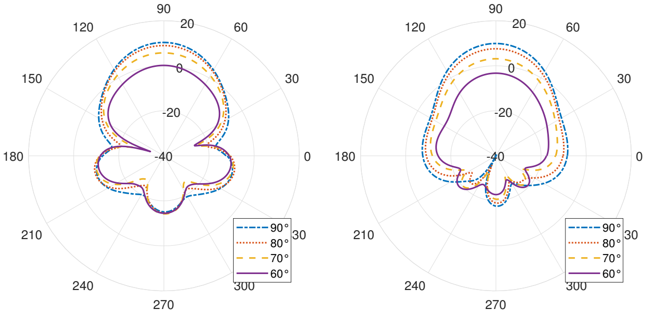
III. RESULTS AND EXPLANATION

Reconfiguration is achieved by adjusting the two parameters shown in Fig. 1c: The distance between the dipole and vertex of the reflector, s, and the angle of the reflector, α. When s is small, 10.2 mm or 12.2 mm, changing α from 90° to 60° creates two nulls in the H-plane, located 73° from the direction of maximum gain on both sides. Since the direction of maximum gain is 90°, the nulls appear at 17° and 163°. For a spacing of $s = 12.2$ mm (Fig. 2a), the differences between the gain at the maximum and at these nulls are 31.7 dB and 33.4 dB for $\alpha = 60^\circ$, but 23.0 dB and 22.8 dB for $\alpha = 90^\circ$. For $s = 10.2$ mm (Fig. 3a), the differences between the gain



(a) (b)

Fig. 2. Comparison of simulated h-planes for dipole-vertex distance of 12.2mm at different folding angles for (a) FSS and (b) no FSS.



(a) (b)

Fig. 3. Comparison of simulated h-planes for dipole-vertex distance of 10.2mm at different folding angle for (a) FSS and (b) no FSS.

at the maximum and at the nulls were 24.85 dB and 33.85 dB for $\alpha = 60°$, but 23.7 dB and 23.0 dB for $\alpha = 90°$.

Comparing these patterns to the case of a solid reflector, it can be observed that these nulls do not appear when a solid reflector is used. For the solid reflector where s = 12.2 mm (Fig. 2b), the difference between the maximum gain and the gains at 17° and 163° are 12.5 dB and 10.8 dB for $\alpha = 60°$, while for $\alpha = 90°$, they are 17.7 dB and 17.3 dB. For a solid reflector with s =10.2 mm (Fig. 3b), these values are 12.4 dB and 9.8 dB for $\alpha = 60°$, and for $\alpha = 90°$, 17.4 dB and 16.9 dB. The gains at different angles are presented in Table I. The data show that only with an FSS does suppression at the null points increase with folding for these smaller spacings.

To maintain a given system efficiency, spacing s between the vertex of the reflector and the feed element must increase as folding angle α decreases, which compensates for reduced radiation resistance [1]. In the simulations presented here, the dipole is very close to the reflector, which explains why the gain generally decreases with the folding angle. However, it does not explain the appearance of nulls.

TABLE I
GAINS AT REFLECTOR ANGLES AND DIPOLE-VERTEX SPACINGS

α, s (°, mm)	**FSS Gain (dB)**			**Solid Gain (dB)**		
	60°	***90°***	***163°***	***60°***	***90°***	***163°***
60, 12.2	−26.3	5.4	−28.0	−10.6	1.9	−8.9
90, 12.2	−11.2	11.8	−11.0	−5.9	11.8	−5.5
60, 10.2	−24.7	0.15	−33.7	−15.7	−3.3	−13.1
90, 10.2	−13.4	10.3	−12.7	−7.5	9.9	−7.0

The FSS may be better at blocking radiation than solid metal, which is evidenced by the excited current patterns in the reflector during simulation. Previous work has shown that by altering the configuration of an FSS, the shape of the radiation pattern can be controlled or steered [9][10]. When folding the reflector, the size and shape of the FSS changes from the perspective of the dipole, even though its 3D size does not. It is possible that this apparent change in the FSS shape is responsible for the different radiation patterns.

IV. CONCLUSION

This paper presents a corner reflector antenna that uses a frequency-selective surface (FSS). The FSS introduces nulls 73° on either side of the direction of maximum radiation. At small vertex-dipole spacings, decreasing the folding angle of the reflector from 90° to 60° increases the absolute depth of the nulls and the difference between the maximum gain and the gains 73° from the direction of maximum gain. The adaptability of this design makes it attractive for many applications.

ACKNOWLEDGEMENT

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