International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 7 Issue 10 Ver II || Oct 2018 || PP 58-61

Broadside 3D Printed Cavity Backed Stacked Antenna

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Abstract: *In this paper, a broadside cavity backed stacked antenna is proposed with E-shaped driven patch and octagonal ring resonator as the parasitic patch to resonate at 14.6 GHz. In this work, staking technique is utilized to concentrate antenna's radiation pattern around antenna's center and consequently antenna's side lobe level (SLL) decreases. Here, to have low weight handy structure, antenna's cavity is made by three dimensional (3D) printed conductive composite instead of metallic shielding cavity.*

Keywords–*Cavity backed antenna,E-shaped patch antenna, stacked antenna, Ku band, Octagonal ring resonator*

Date of Submission: 05-10-2018 Date of acceptance: 17-10-2018

I. INTRODUCTION

In many works like [1-3], by cutting slots in simple microstrip patch antenna and modifying antenna's shape to E-, H- or U-shaped, bandwidth (BW) of antenna increases. Moreover, in some works such as [4], stacked configuration is used by adding a parasitic patch above driven patch (fed by coaxial feeding) for further BW increase. Beside BW enhancement, in some works like [5], stacking technique is utilized for modifying far field radiation pattern of antennas and increase their directivity. In this work, similar to [me], E-shaped patch antenna is utilized as driven patch and to prevent radiation pattern squint from broadside due to surface current at edges of E-shaped patch, a thin dielectric cover layer is used. Utilization of dielectric cover layer causes antenna's radiation pattern concentrate at specific direction (broadside in this work). To improve directivity of the antenna, the parasitic patch is added on cover layer similar to [4-5]. Different shapes of parasitic patches have different effect on shifting main lobe and side lobe level of tacked antennas as discussed in [4]. Here, to have directive broadside radiation pattern, octagonal ring resonator is chosen as the parasitic patch to obtain high quality factor (Q-factor) at resonance frequency in the designed antenna as explained in [6]. In addition as discussed in [7], to have good shielding, minimum back lobe and handy configuration, a metallic cavity is designed in back of the antenna. In this work, the cavity backed design is used for the same purpose but unlike [7], instead of metal, the cavity is made from three dimensional (3D)printed conductive composite with honeycomb internal mesh and 20% volume content of poly lactic-acid (PLA), which its shielding effectiveness is studied in [8] . In [8], the proposed 3D printed conductive composite can be used as electromagnetic interference (EMI) shielding material with same shielding effectiveness as metal but less weight. Hence, the handy low weight cavity backed E-shaped stacked antenna can be used in many application that needs directive, compact and lightweight antennas such microwave/millimeter wave imaging cameras, which need to antenna's pair with minimum distance as possible as explained in [9]. Here, the proposed antenna is optimized in CST MICROWAVE STUDIO® to work at 14.6 GHz with gain more than 7.5 dB.

II. DESIGN PROCEDURE

In Fig. 1, the structure of the proposed cavity backed E-shaped stacked antenna is depicted. The proposed antenna's dimensions are adjusted to resonance in Ku- band (12.5-15 GHz) when RO4350B with ε_r =3.5 and 60 mil thickness is chosen as the substrate of the driven patch and RT5880 with ε_r =2.2 and 10 mil thickness (h_1) is the cover layer's substrate. To have resonance at 14.6 GHz, W is chosen 20 mm and L = 30 mm, r = 7.5 mm, l_s= 10 mm and w_s = 7.5 mm and simulation results in follow are prepared by considering these dimensions.

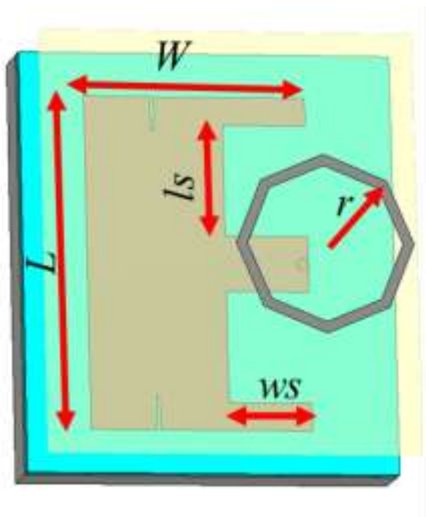
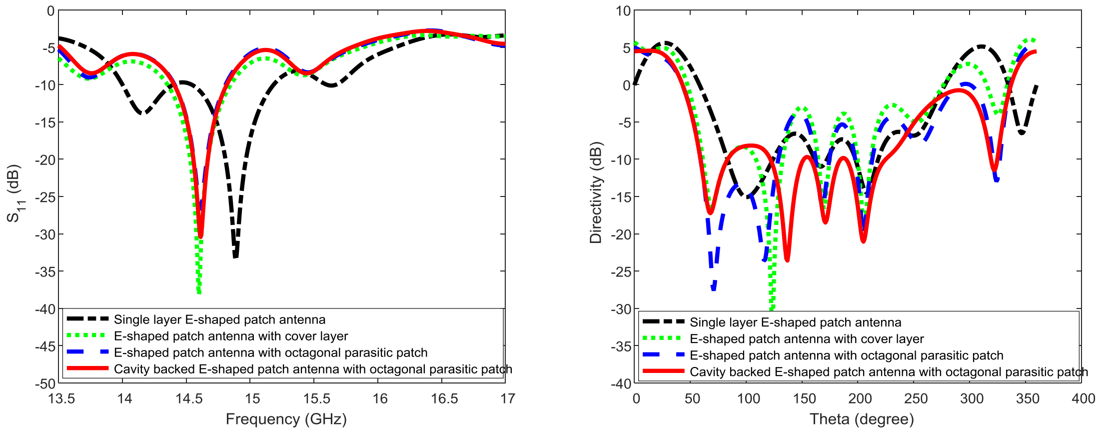


Figure 1. The proposed 3D printed cavity backed stacked antenna.

First, the effect of adding cover layer is studied in Fig. 2 based on simulated reflection coefficient ($|S_{11}|$) and antenna's directivity at E –plane (Phi = 0°). As seen in Fig. 2 (a), adding cover layer on top of the E-shaped antenna causes resonance frequency shifts toward lower frequency (from 14.9 GHz to 14.6 GHz) and Q-factor of the antenna increases. However, by adding octagonal parasitic patch, Q-factor of the proposed antenna decreases while side lobe level (SLL) of the antenna degrades as seen in Fig. 2(b). In Fig. 2(b), the single layer E-shaped antenna has two main lobes around Theta = 25° and 310°. By adding cover layer, one of main lobes shifts toward Theta = 0° (broadside), while the second lobe still is around Theta = 310°. Adding octagonal parasitic patch reduces level of the lobe at Theta = 310° and SLL. Hence, by using stacking technique, one main lobe around Theta = 0° (broadside) is created with less SLL compare with single layer E-shaped antenna. Moreover, by preparing the cavity in backside of the antenna, Q-factor increases as shown in Fig. 2(a) and antenna's back lobe (around Theta = 180°) decreases as seen in Fig. 2(b).



(a) (b)

Figure 2.Simulated (a) $|S_{11}|$ and (b) directivity of single layer E-shaped antenna, E-shaped patch antenna with cover layer, E-shaped patch antenna with octagonal parasitic patch and the proposed antenna.

Next, the effect of parasitic patch's shape on antenna's specification is studied. Here, simulations are prepared for two cases as the parasitic patch. Octagonal ring resonator as the example of parasitic patch with sharp edges and circular ring resonator as the parasitic patch with smooth boundaries. In this way, edge's effect of the parasitic patch on radiation confinement of the stacked antenna is demonstrated. As seen in Fig. 3, SLL of the designed antenna with octagonal parasitic patch with sharp edges is less than SLL when circular parasitic patch is chosen. As demonstrated in [10], surface current density is more at edges of the octagonal resonator that cause radiation mostly is focused around resonator's edges (around Theta = 0°) instead of spreading other directions.

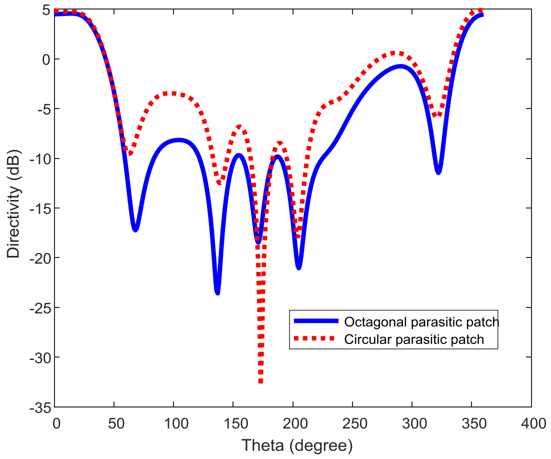
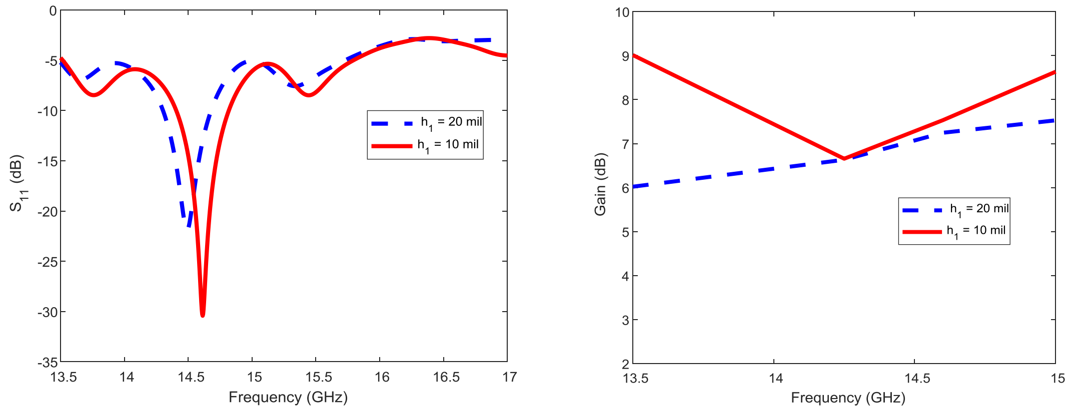


Figure 3. Antenna's directivity at plane Phi = 0° for octagonal and circular ring resonator as the parasitic patch.

Finally, the effect of cover layer's thickness on antenna's specification is studied. Simulated $|S_{11}|$ is depicted in Fig. 4(a) for the proposed antenna with 10 and 20 mil cover layer's thickness. As seen, by increasing thickness, resonance frequency shifts toward lower frequency and Q-factor decreases. Moreover, antenna's gain reduces by increasing cover layer's thickness as shown in Fig. 4(b). Here, by choosing 10 mil cover layer, at antenna's resonance frequency, gain of the antenna reaches above 7.5 dB.



(a) (b)

Figure 4. (a) Simulated $|S_{11}|$ and (b) gain of the proposed antenna for 10 and 20 mil thickness of cover layer.

III. CONCLUSION

In this work, the broadside cavity backed stacked antenna is designed to work at 14.6 GHz. Here, by using stacking technique (adding thin cover layer and octagonal parasitic patch), antenna's main lobe shifts toward Theta = 0° from 25° and the magnitude of second main lobe at 310° decreases. Moreover, by using 3D printed conductive composite with honeycomb internal mesh and 20% volume content of poly lactic-acid (PLA) to make antenna's shielding cavity, antenna's weight decreases dramatically without shielding effectiveness degrades.

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