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L-PROBE FED CIRCULAR POLARIZED WIDEBAND PLANAR PATCH ANTENNA ON CYLINDRICAL STRUCTURE

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Abstract—In this paper, the characteristics of an L probe fed planar rectangular patch antenna mounted on a cylindrical surface for circular polarization is investigated. To obtain a large bandwidth an L probe feed is used which is in the shape of a fork attached to a coaxial cable and is placed under a corner of the patch antenna. Simulation results, obtained via HFSS, on the return loss and radiation pattern of the antenna for circular polarization are presented. Results show an impedance bandwidth of 74.6%, an average gain of 7.5 dBi with stable radiation patterns across the entire passband and a bandwidth of 58% for AR $<$ 3 dB.

1. INTRODUCTION

Due to their conformability with the hosting structure, microstrip patch antennas find many applications related to curved structures such as cylindrical structures, high-speed aircrafts and spacecrafts, [1]. In recent years, there has been a growth of the communication services such as the radar, Global Positioning Satellite, mobile communication systems, etc. In many of applications wideband and circular polarized, CP, antennas are required. The feeding structure of CP antennas may be divided into single and hybrid type. A single-feeding CP antenna provides simple structure without the need of an external 90 degree hybrid. However, it has narrow axial ratio bandwidth. Hybrid feeding which are complex and difficult to manufacture provide wider axial ratio bandwidth. In CP antenna, axial ratio bandwidth is the most important factor in design. Therefore, many kinds of CP antennas have been studied to obtain wide axial ratio bandwidth. Furthermore, conventional microstrip antenna, has narrow impedance bandwidth.

Many techniques have been proposed to enhance the radiation pattern [2, 3] or the bandwidth of microstrip antennas on cylindrical structures. In [4], to obtain a wider impedance bandwidth compared to a single patch antenna, two conformal patches are stacked on top of each other leading to a 13.4% bandwidth over the frequency range of 1.81 to 2.07 GHz. In [5, 6] a similar structure analysed via a full wave technique leading to some 25% impedance bandwidth is reported. To increase the bandwidth [7] has used a small patch connected to a coaxial probe to capacitively feed the main stacked patch antennas leading to some 29% bandwidth. Rather than having a conformal patch antenna on the cylindrical surface, [8] has used a planar patch fed by L-probe leading to an enhanced bandwidth of 48% over 2–3.2 GHz band. In that paper the effect of various radius of cylinder is also discussed.

The slot antenna due to its adaptability and high power capability is also a good candidate for conformal cylindrical antennas. There has been a lot of work on such slot antennas [9, 10] considering various feed types and dielectric covers.

Circularly polarized planar antennas have been realized by a variety of structures, [11–13]. The circular polarization condition for a corner probe fed cylindrical rectangular microstrip patch antenna is investigated in [14]. In that paper a 3-dB axial ratio bandwidth of 25 MHz at center frequency of 2.195 GHz is reported.

In this paper a wideband circular polarized planar patch antenna on a cylindrical structure is studied. To obtain the high bandwidth a fork-like L-probe is used. The dimension of the patch as well as the position of the probe feed are optimized leading to a wideband circular polarized behavior. Ansoft HFSS is used to simulate the return loss, the E- and H-plane radiation patterns at various frequencies and the gain over the band.

2. ANTENNA CONFIGURATION

The antenna configuration is shown in Fig. 1, where a rectangular planar patch placed on a cylindrical structure is fed at a corner through an L-probe placed underneath the patch. The new L-probe feed which is in the shape of a fork is attached to a coaxial cable. The radius of the cylinder, R, is set between 50 to 100 mm. The patch is mounted above the grounded cylindrical substrate at a height of S equal to 14 mm. To satisfy the circular polarization conditions, i.e., equal magnitude and 90 phase difference between the field components, several simulations have taken place from which the width, W_p and the length L_p of the rectangular patch are found to be 43 mm and 41 mm, respectively. The position and the orientation of the L-probe feed is also a key parameter

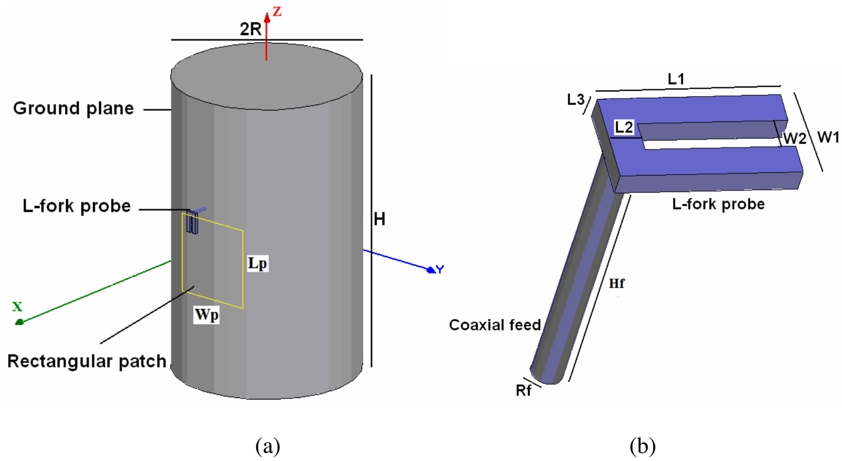

Figure 1. Configuration of the fork L-probe fed planar patch antenna mounted on a cylinder. (a) The cylindrical antenna structure, (b) The L-fork probe. $R = 50$ mm, $H = 160$ mm, $L_p = 41$ mm, $W_p = 43$ mm, $L_1 = 11.3$ mm, $L_2 = 2$ mm, $W_1 = 6$ mm, $W_2 = 2$ mm, $L_3 = 1.17$ mm, $R_f = 1$ mm and $H_f = 9.1$ mm.

for having circular polarization. The probe is placed at a corner as shown in Fig. 1 and is displaced 1 mm from each edge of the patch with its fingers pointed in the z direction. With the dimensions stated, this orientation of the L-probe provides the best circular polarization as well as broad band behavior. As shown in Fig. 1(a) the dimensions of the L-fork probe W_1, W_2, L_1, L_2 and L_3, are set at 6 mm, 2 mm, and 11.3 mm, 2 mm, 1.17 mm, respectively. The height of the coaxial probe, H_f above the grounded cylinder is 9.1 mm and its radius R_f is 1 mm.

3. SIMULATED RESULTS

The cylindrical structure of Fig. 1 has been simulated through a commercially available finite element package, HFSS. Initially, cylinders with radiuses 50 and 100 mm have been analyzed while keeping the rest of the antenna parameters fixed. Fig. 2 shows the return loss of the antenna for these two cylinder radiuses. From this figure, it can be seen that the impedance bandwidth of the L-fork probe fed patch antenna increases when the radius of the cylindrical structure decreases (higher radiuses leads to higher return loss). Thus, in the rest of this analysis a cylinder with radius of 50 mm is used. This

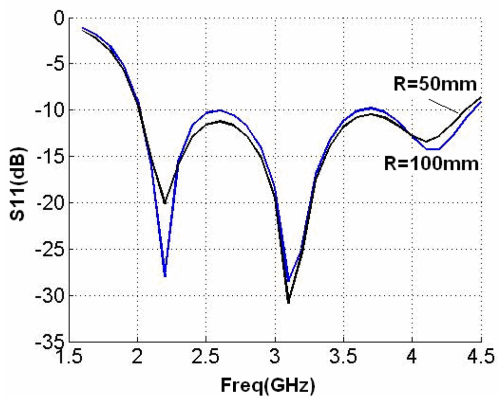

Figure 2. Simulated return loss of L-fork probe fed planar patch antenna mounted on cylinders with two different radiuses.

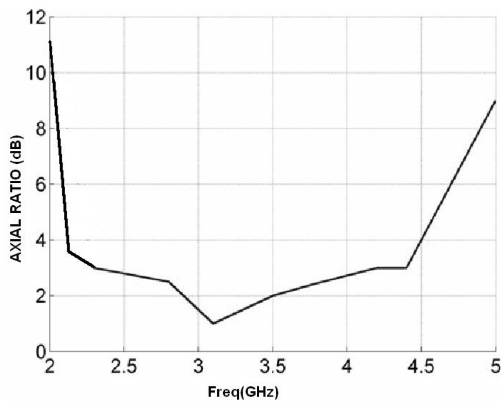

Figure 3. Axial ratio magnitude versus frequency for the fork L-probe patch on cylindrical structure.

bandwidth increase was also reported in [8] for an ordinary L-probe feed, where a maximum of 48% bandwidth was obtained. Fig. 2 shows an impedance bandwidth of almost 74% (based on centre frequency of 3.2 GHz) which is higher by some 26% than that of the single L-probe feed of [8].

Similar to other circularly polarized microstrip antennas fed at a corner [6], in the present microstrip antenna, circular polarization is obtained by the excitation of two orthogonal modes with 90 degree phase difference between them. Simulated axial ratio (AR) magnitude versus frequency is shown in Fig. 3.

Based on the results of this figure as well as having a 90 degree phase difference, this antenna has a 3-dB axial ratio bandwidths of 58% ranging from 2.2 to 4.0 GHz which lies in the range of the result of Fig. 2.

Figure 4 shows the simulated radiation patterns in the xy and xz

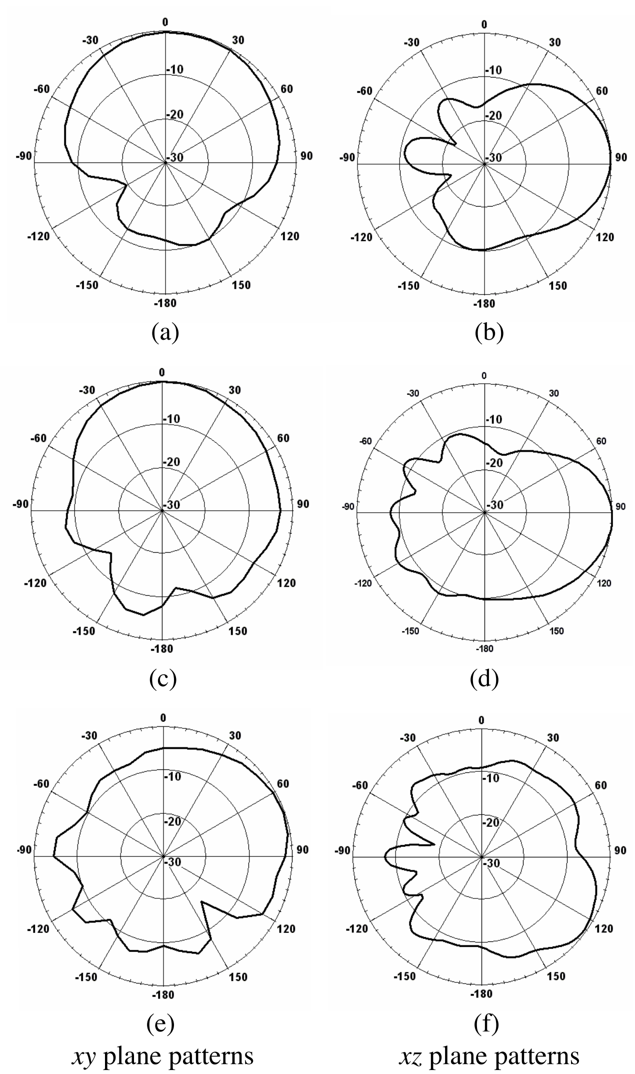

Figure 4. Simulated radiation patterns in the xy and xz planes at 2.1 GHz ((a), (b)), 3.1 GHz ((c), (d)) and 4 GHz ((e), (f)) of the fork probe fed planar patch antenna.

planes at three different frequencies, 2.1 GHz, 3.1 GHz and 4 GHz over the bandwidth. Good radiation patterns over both xy and xz planes are noticed, only at higher frequencies a tilt in the main beam occurs. The variation of the antenna gain with frequency is shown in Fig. 5. At the center frequency, 3.1 GHz, more than 7.6 dBi for gain is obtainable.

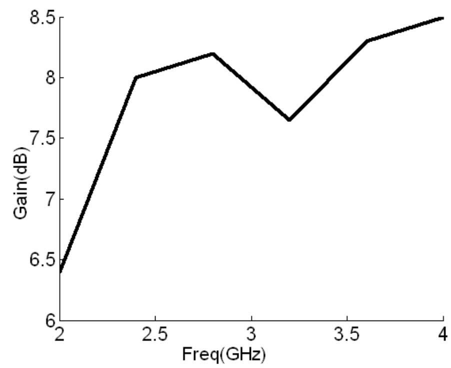

Figure 5. Variation of Gain with frequency of the fork probe fed planar patch antenna.

4. CONCLUSION

The characteristics of a wideband L-probe fed planar rectangular patch antenna mounted on a cylindrical surface for circular polarization is investigated. To obtain a large bandwidth the L-probe feed is used which is in the shape of a fork attached to a coaxial cable and is placed under a corner of the patch antenna. Simulation results on the return loss show a bandwidth of 74% and a bandwidth of 58% (2.2–4 GHz) for AR < 3 dB. Radiation patterns of the antenna for circular polarization over various frequencies show an almost stable pattern with a gain of 7 to 8.5 dBi over the bandwidth.

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