S-band Circular Polarization Patch Antenna Design for the Large Curvature Conformal Structure

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Abstract— A circular polarization patch antenna operating at S-band is proposed which is complaint with a large curvature column structure. The coupling effects between the conformed antenna and the based structure are considered accurately in the refined simulation models and impedance performance has been illustrated in the paper. The designed maximal gain in the normal direction of the antenna aperture reaches 7 dBi possessing the polarization axial ratio from 0.3 dB to 3.2 dB within ±45° scanning volume.

1. INTRODUCTION

Conformal antennas are growing considerably in their adaptabilities for the applications in which the impacts of the aerodynamic shapes are essential to be concerned [1, 2]. Generally, microstrip patches are selected in the conformal antenna designs due to the low profile characteristic and abilities for the resemblance with the exterior shapes, especially for the aircraft shells.

Recently, the increasing requirements of the low radar cross section (RCS) and wide scan angles boost the further developments of conformal phased array systems [3]. Adequate achievements have been done almost following the same speculation that the array consists of tiny planar antenna elements ranged in certain radius and is approximately identical structure with the carrier. A typical conformal array antenna has been shown in Figure 1 as radar seeker for missile-borne requirement [4].

However, the missile-borne applications, such as communication and remote metering, are gradually operating at S-band [5]. The conformal patch antenna also needs to be circular polarization and pasted on the surface not in common with radar indicator antenna. In some case, the patch dimension is nearly equivalent to the missile radius. Accordingly, the approximate planar theory is disabled and the new investigation is put forward to optimize the patch traits giving attention to conformal circular polarization design.

In this paper, a conformal patch antenna working at S-band with circular polarization is designed on a column in large curvature, namely, the column radius is nearly equivalent to the patch dimension. An optimized model with the reasonable parameters is framed. Then, the effective calculated results are obtained simultaneously. The simulated maximal gain in the normal direction of the antenna reaches 7 dBi with the polarization axial ratio from 0.3 dB to 3.2 dB in the direction of ±45° scanning scope.

Figure 1: Conformal array antenna for missile-borne.

2. BASE ANTENNA CONFIGURATION

The traditional patch antenna is designed with circular polarization characteristic firstly. It is basically to compute the patch obeying classical theory and design the feeding structure using strip lines. The dimensions of the patch can be calculated according to the operating frequency, dielectric constant and the thick of the material, meanwhile the feed line is carried out in the same way. Arlon DiClad880 is selected to as the substrate material. Its dielectric constant is 2.2. The thicknesses of the two substrates are 1.016 mm. The structure of the planar antenna is given in

Figure 2. As shown, the element is composed of an upper patch, a feed-line in medium, a ground plane and two substrate layers.

In Figure 3, W_a is the length of the square radiation patch. The active termination of the feed-line is W_0 in wide and the width of the transmission part is W_1. In order to obtain the circular polarization, the feed-line differ between the input and two feed points is reasonable designed as the length which is equally 90° phase postponed to decide the vortical direction of the circular polarization.

In this paper, a right-handed circular polarization is simulated by HFSS. Calculated parameters are: $W\_a = 43$ mm, $W_0 = 6.2$ mm, $W_1 = 4$ mm and the length differ is 20.49 mm. The simulated results are revealed in Figure 4. The simulated polarization axial ratio is below 3 dB between ±80° and below 1.4 dB in the direction of ±45° scanning space with HFSS software. A maximal gain is obtained about 8 dBi in normal direction. The VSWR of input port is 1.69 at 2.25 GHz.

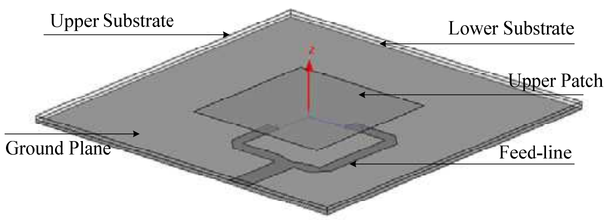

Figure 2: Geometry of the planar antenna.

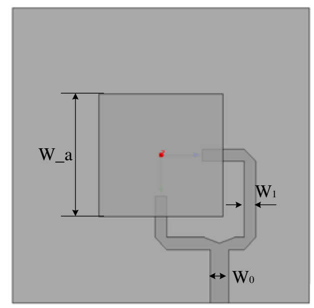

Figure 3: Parameters of the planar antenna.

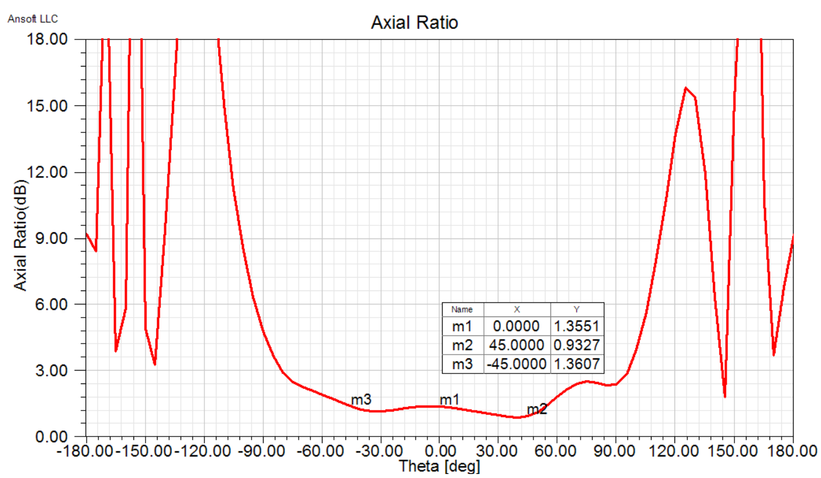

Figure 4: Axial ratio of the planar antenna at 2.25 GHz.

3. CONFORMAL ANTENNA DESIGN AND RESULTS

A circular polarization patch antenna working at 2.25 GHz is designed which is conformal on a column in large curvature. The conformal antenna model is composed of an exterior patch, a feed-line in middle, an inner ground plane and two substrate layers. It is also used the substrate material Arlon DiClad880 with the same dielectric constant 2.2 and the thicknesses of the two substrates 1.016 mm. The structure of the conformal antenna model is given in Figure 5.

As illustrated in Figure 5, the pillar radius r is equal to 50 mm and nearly equivalent to patch dimension. W_b is the length of the exterior square patch. W_3 is the width of the active termination of the feed-line and W_4 is the size of the transmission part. Accordingly, the approximate planar theory is disabled and the application is put forward to optimize the patch characteristics giving attention to conformal circular polarization design.

At first, a model is simulated in which the parameters are identical to the planar antenna model with $W\_b = W\_a = 42$ mm, $W_3 = W_0 = 6.2$ mm, $W_4 = W_1 = 4$ mm and the path differ 20.49 mm.

The calculated result is shown in Figure 6. The polarization axial ratio is all above 16.7 dB between $\pm 45°$. The circular polarization characteristic is destroyed completely. Due to this phenomenon, it is significant to optimize the parameters in the next model by changing the sizes.

According to the requirement of the right-handed circular polarization, the path differ of two feed-lines between the input and two feed points is considerably optimized to produce 90° phase delay, which is vital factor to the conformal antenna achieving circular polarization. Once the planar antenna is conformal on a pillar, the characteristic of the patch and feed-line would be changed, especially in the changing of equivalent length of the transmission part in path differ.

The second model is built and simulated by optimizing parameters of the conformal antenna. After tuning the W_b, W_3, W_4 and path differ, the preferable results are accomplished as shown in

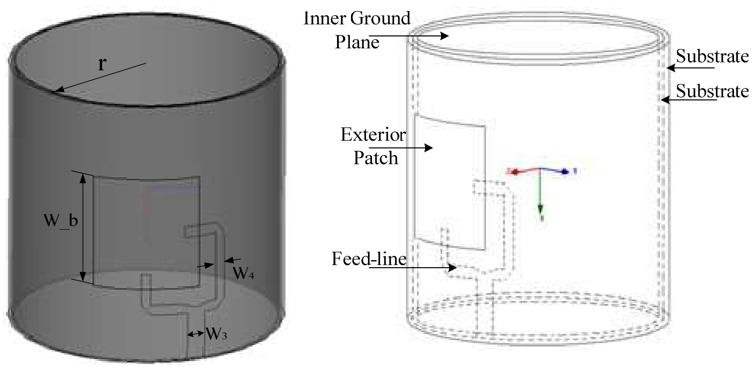

Figure 5: Geometry of the conformal antenna.

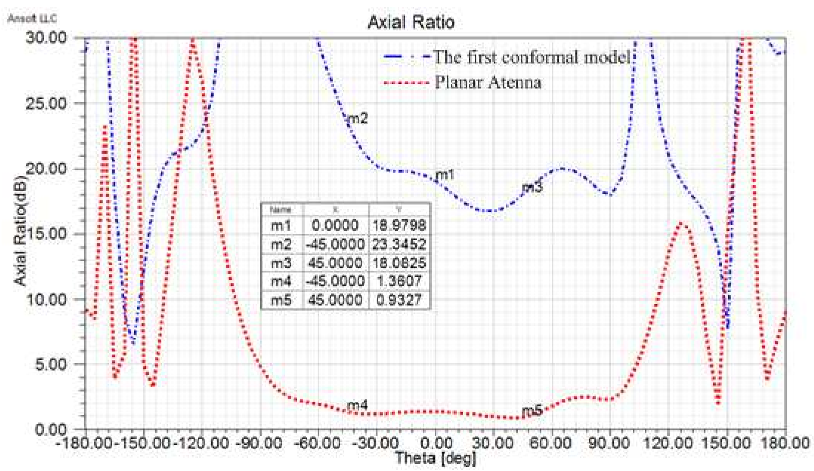

Figure 6: Axial ratio of the planar antenna and the first conformal model at 2.25 GHz.

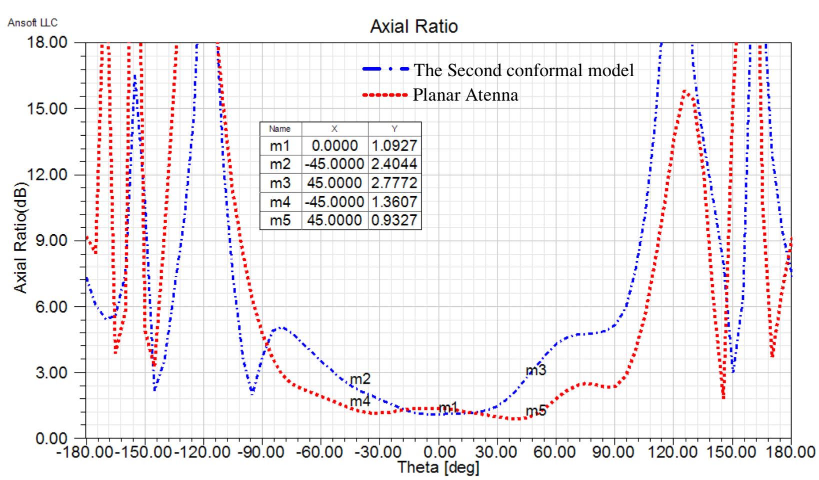

Figure 7: Axial ratio of the planar antenna and the second conformal model at 2.25 GHz.

Figure 7. The optimized results by HFSS show a maximal gain of 7 dBi in normal direction with the polarization axial ratio from 0.3 dB to 3.2 dB in the direction of ±45° scanning scope.

In this condition, $W\_b = 43\,\mathrm{mm}$, $W_3 = 6.5\,\mathrm{mm}$, $W_4 = 4\,\mathrm{mm}$, and the path differ changed to 20.07 mm. The most improvement is the path differ which determines the phase relationship mostly.

4. CONCLUSIONS

This paper designs a typical circular polarization patch antenna working at S-band which is conformal on a column with large curvature. An optimized model with the reasonable parameters is constructed and the simulated results are obtained simultaneously. The optimized results show a maximal gain of 7 dBi in normal direction and the polarization axial ratio from 0.3 dB to 3.2 dB in the direction of ±45° scanning scope.

In practical application, the path differ of double feed-points is the most important factor to control the phase relationship. It must be calculated carefully to obtain the anticipant results.

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