Investigations of Wideband Circular Polarized High Gain Microstrip Patch Array Antenna at Ku-band on Curved Surfaces

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***Abstract*—A wideband right hand circularly polarized (RHCP) high gain 8×8 microstrip patch array antenna operating at Ku-band on curved surface of different diameters is investigated. The planar surface 8×8 microstrip patch array parameters are compared to the curved surface 8×8 microstrip patch array parameters. The degradation of 3dB axial ratio, gain, and radiation pattern is observed from the comparison. Matching performance is almost unaltered due to the curvature.**

I. Introduction

Conformal array antennas can find applications on aircrafts, missiles and unmanned aerial vehicles (UAVs). A high gain wideband circularly polarized array antennas at Ku-band is designed with two stages of sequential rotation in [1]. Radiation pattern characteristics of a cylindrical array at different radii is investigated in [2]. A planar wideband high gain 8×8 microstrip patch array antenna is designed and studied. The designed array antenna consists of three stages of clockwise sequential rotation for RHCP. By wrapping the patch array antenna on curved surfaces with different diameters of 12inch, 18inch, and 24inch, the impedance matching, axial ratio, RHCP gain, and 2D radiation pattern results are compared to a planar surface antenna array.

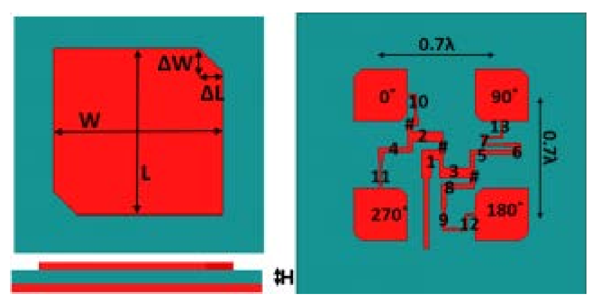
II. Curved Surface Study of 8×8 Microstrip Sequentially Rotated Patch Array Antennas

A. Three stage sequentially rotated 8×8 patch array antennas

The single radiating element of the array is a conventional truncated corner square microstrip patch antenna with RHCP (Fig. 1(a)) [3]. Full wave analysis based investigations of high gain 8×8 microstrip patch array is performed on different radii of curved surfaces using Ansys HFSS v.16. The dimensions of the square patch are L= W = 7.61mm with truncated corners ΔL= ΔW = 1.084mm which is etched on a RT/Duroid 5880 substrate ($\varepsilon_r = 2.2$, $\tan\theta = 0.002$) of thickness H = 30 mils. The 3dB axial ratio bandwidth and impedance matching bandwidth can be increased with sequential rotation of these radiating elements. Each truncated patch is sequentially rotated to obtain wideband circular polarization which are excited with equal power and time delays of 0°, 90°, 180°, and 270°. The three stages of clockwise sequential rotation was used in 8×8 array as shown in Fig. 2(a) The inter-element spacing between the radiating elements is 0.7λ at each stages where λ is free space wavelength at 12.50GHz. The feed network for 8×8 array is achieved by sequentially rotating the 2×2 feed network.

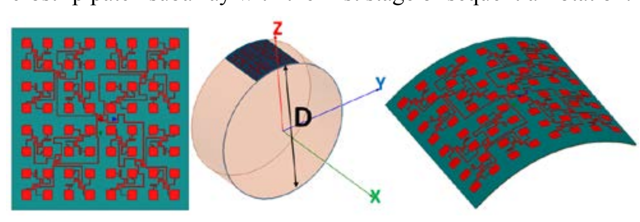
B. Curved surface study results

The 8×8 patch array is curved as shown in Fig. 2(b) along Y axis (Phi = 90˚ plane) to study the effect of the curved surface on the patch array performance. The diameter for curved surface are 12inch, 18inch, and 24inch. Fig. 2(c) shows the 12inch diameter since the structure would increase simulation complexity due to the large radiation boundary.



(a) (b)

Fig. 1. Geometry of the truncated corner square microstrip patch antenna with right hand circular polarization (RHCP) and (b) 2×2 microstrip patch subarray with the first stage of sequential rotation.



(a) (b) (c)

Fig. 2. 8×8 microstrip patch array antennas (a) Planar array, (b) Array on a cylindrical surface and (c) Array on a partial curved surface geometry of diameter D.

Fig. 3 shows wideband impedance matching performance at $S_{11} < -10$ dB from 11.0GHz to 14GHz with 24% fractional bandwidth for planar and curvature studies. Thus the curve surface does not affect matching performance. On the contrary,

Fig. 4 shows axial ratio (AR) for planar and curvature studies. The AR bandwidth is wider on the planar surface but deteriorate with the increase in diameter of the curved surface. The curved surface reduces the effect of the sequential rotation in comparison to a planar surface thus changing the AR.

The RHCP gain over frequency of interest and array pattern is different between the planar and curvature studies. On a planar surface, the radiation pattern would accumulate and go in one direction. On the other hand in the curved surface, the inter-element spacing is varying thus making the array non-uniformly spaced. Also, the patch array is on a curved surface, not all of the radiating elements is radiating in the same direction. Fig. 5 shows RHCP gain vs frequency for all the cases for planar and curvature studies. It is shown that at 12inch diameter, the gain dropped more than 3dB over the frequency of interest. This means that the efficiency/gain for more than 12inch diameter would results in such much more degradation. However, the 24inch diameter is better because it is closer to the planar array case.

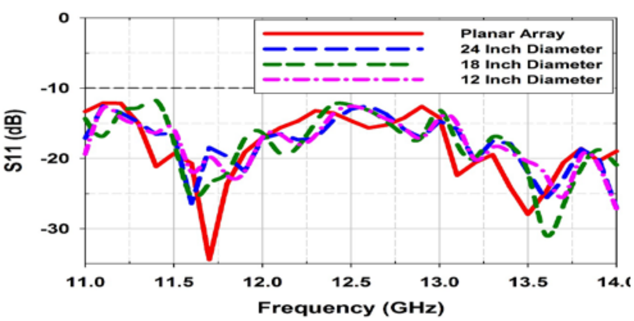


Fig. 3. Impedance matching (S_{11}, dB) vs. frequency (GHz)

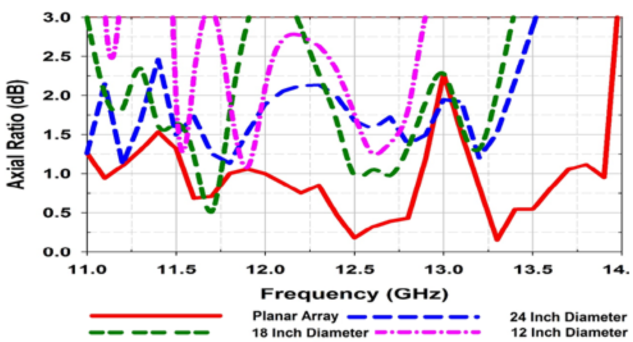


Fig. 4. Axial ratio (dB) vs. frequency (GHz)

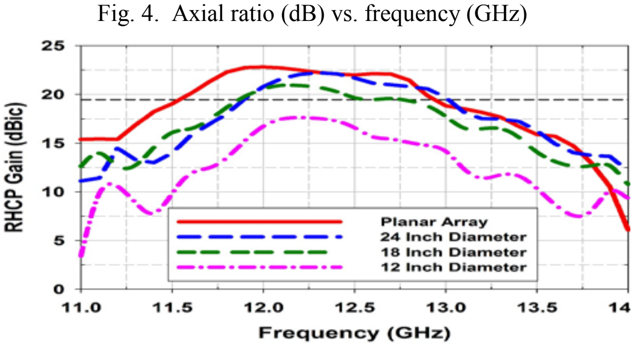
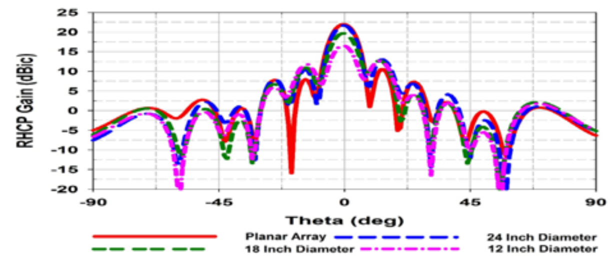
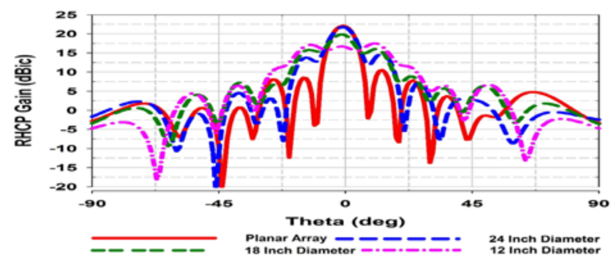


Fig. 5. RHCP gain (dBic) vs frequency (GHz)

Figs. 6(a-b) show 2D radiation patterns at 12.5GHz along both Phi = 0º and 90º cut planes, respectively. The radiation pattern performance remains almost the same along X axis (Phi = 0º cut plane) except the reduction in gain. Compared to this, along the Y axis (curving axis, Phi = 90º), the radiation pattern is getting spread because of the slight change in the inter-element spacing and that the radiating elements is radiating slightly in different angle and therefore with increase in the curvature, the radiation patterns are degrading. In Table I additional radiation characteristics are summarized.



(a)



(b)

Fig. 6. Radiation patterns at 12.5 GHz for (a) Phi 0˚ (X axis) and (b) Phi 90˚ (Y axis) cut planes with planar case and array with curvatures.

TABLE I. Radiation performance comparison at 12.5GHz

Array Geometry		Planar Array	24 inch	18 inch	12 inch
Gain (dBic)		21.98	21.68	19.63	16.7
Sidelobe Level (dB)	*Phi 0˚*	11.98	8.72	6.95	3
	Phi 90˚	11.98	7.13	3.75	14.9
Peak Cross polarization (dB)		20	19.9	18	18

III. Conclusions and Future Study

Planar surface array was designed and compared curved surface to study effects of curving. Array characteristics like axial ratio, gain and radiation patterns are getting degraded with increase in the curvature. The antenna has been prototyped and measurements will be performed soon. Measured results will be presented during the conference.

References

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