A Comparative Study on Arc Conformal Arrays for Different Curvatures

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Abstract— ***This paper presents design and development of conformal antennas in cylindrical curved surfaces. 4 element and 8 element linear, circular as well as conformal arrays have been designed with different curvatures and their features viz. gain and beamwidth have been compared. The design has been carried out using MATLAB and the optimization has been carried out using 3D EM simulation software HFSS. The linear as well as conformal arrays have been fabricated on RT Duroid substrate of thickness 5 mil and the measured results are also presented.***

Keywords—**Conformal array, circular array, inset fed patch element, Phased array.**

I. INTRODUCTION

Conformal antennas as name implies is “to conform” or to take the shape of the host or the platform over which it operates. The IEEE standard definition for antennas gives the following definition (IEEE STANDARD 145-2013)[1]: 'An antenna that conforms to a surface whose shape is determined by considerations other than electromagnetic; for example, aerodynamic or hydrodynamic'. When a surface like an arc is taken into consideration for arrays, it inherently improves the beam scanning capability compared to traditional linear or planar arrays. Applications of conformal arrays are vast especially for military application, these arrays would preserve the aerodynamic structure of the aircraft or missile or UAVs. While the civilian applications include the communication base stations that do not look congested with different sectorial antennas rather uses a cylindrical antenna, and can be used on high speed automobiles as collision warning radars etc. Since the antenna takes the shape of the platform, so its performance and radiation pattern drastically changes from conventional planar arrays[6,7,8].

The application for wide beam width can be seen for Synthetic Aperture Radars (SAR). A cylindrical conformal array [4] has a potential to result in 360^0 coverage, either with narrow beams, omnidirectional beam or multiple beams that can be steered around. The conformal arrays were first designed during 1930s, where an array of dipole elements were arranged in a circular formation, resulting in a circular array, this was studied by Chireix [5]. Later on, in the 1950s, Knudsen[6] published a lot related to conformal arrays.

Based on extensive survey of literature on conformal array it indicates some of the unresolved issues[1] viz. no defined general method exists to perform mathematical calculation on conformal arrays, and they are not well established as compared to linear or planar antenna arrays[2]. There are only iterative algorithms that are mathematically complex to solve for finding array weights and phases, so that the antenna radiation pattern could be improved[3]. The effects of mutual coupling vary greatly depending on the geometry on the profile more than the element spacing or weights[4,5] The potential to tap the wide beamwidth capability of conformal antennas are still under research and experimentation.

II. ANTENNA ELEMENT AND FEED NETWORK

An inset fed microstrip patch antenna element has been chosen as the antenna element due to its easy integration with power divider/combiner networks. The antenna element has been designed to give again of 5dB with a return loss of -10dB. Corporate feed networks are designed using Advanced Design System(ADS) electromagnetic simulation software in order to feed the antenna array. The antenna element and the feed network has been designed and fabricated using RT duroid 5880 substrate with thickness of 5 mil and permittivity 2.2 with a loss tangent of 0.0009.

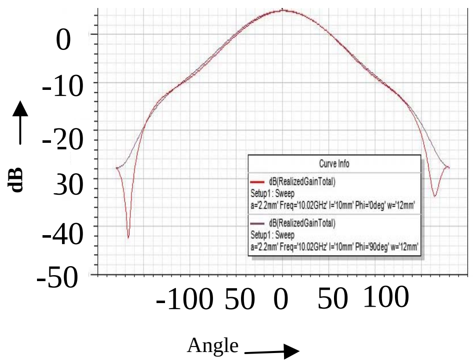


Figure 1 EM Simulated Radiation pattern of Element

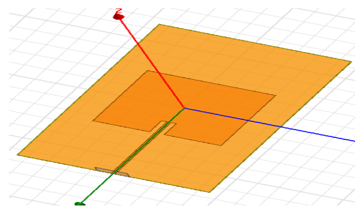
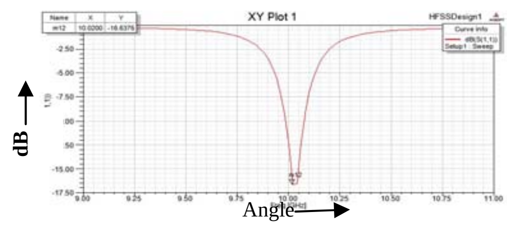


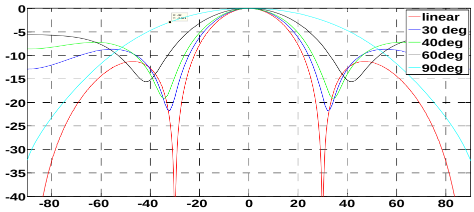
Figure 2 EM Model of Inset fed microstrip patch antenna element



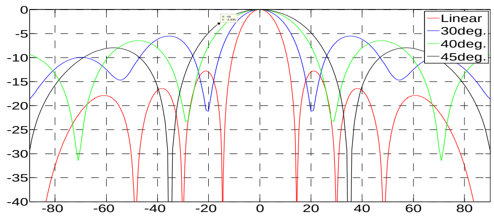
III. DESIGN AND DEVELOPMENT OF ARRAYS

Arrays with 4 element and 8 element have been considered for design realization. Two 4 element arrays are designed with angle of curvature 30° and 40° with halfwavelength interelement spacing. Linear, circular and conformal arrays are designed in MATLAB and the comparison is shown Table-I for 4 element array. Linear and circular array plots are shown in Figure 4. The Simulations have been carried out in X-band frequency 10GHz. The arrays are designed and analysed in terms of Gain, Radiation pattern and half power beamwidth. The arrays have been optimised using HFSS. Figure 5 shows the model of linear 4 element and 8 element arrays. The Simulated Return losses are given in Figure 6. Figure 7 shows the fabricated antenna arrays with different curvatures.

Figure 3 EM Optimised Return Loss of Antenna Element



(a) 4 Element

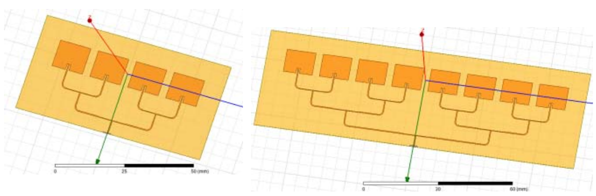


(b) 8 Element

Figure 4 Radiation Pattern of Linear/Circular Array with different Curvatures.

Curvature	Circular		Conformal	
	Gain	BW	Gain	BW
Linear	11.5	26	9.9	25
30 deg	11.2	28	5.8	62
40deg	10.6	32	3.6	110

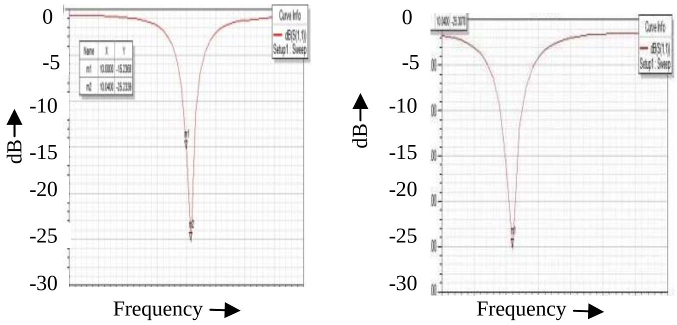
Table 1 Gain and Beamwidth of 4 Element Arrays(Simulated)



(a) (b)

Figure 5. EM Model of Array with feed network.

(a) 4 Element (b) 8 Element



(b) 4 Element (b) 8 Element

Figure 6 Return Loss of Linear Arrays.

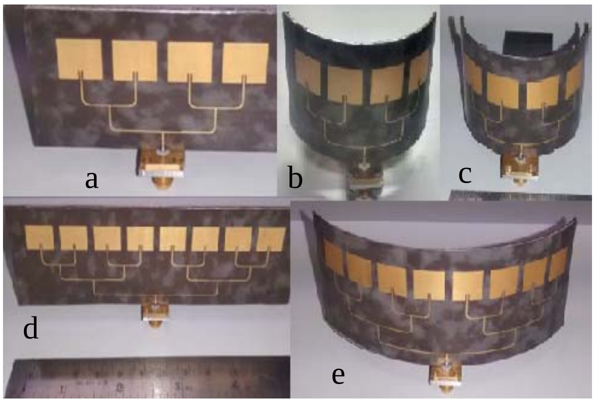


Figure 7: Array prototypes (a) Linear 4 element, (b)Conformal 4 element 30^0 curvature, (c)Conformal 4 element 40^0 curvature,(d) Linear 8 element (e)Conformal 8 element 30^0 curvature

IV. RESULTS

The Arrays have been fabricated using RT duroid 5880 substrate with thickness of 5 mil. These subsequent graphs show the comparison of the radiation pattern from MATLAB, HFSS simulation and measured result from antenna chamber. All the results from various iterations were normalized for comparison.

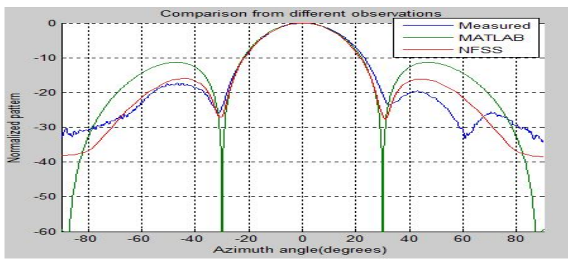


Figure 8: Comparisons of 4 element linear array result from Measured, MATLAB and HFSS tools

From figure 8 we can deduce that the measured pattern result from antenna chamber for 4 element linear array is close to simulated results from HFSS and MATLAB tools. The Sidelobes of the measured patterns are not formed with null filling due to some phase errors inherent in the fabrication and assembly of the array.

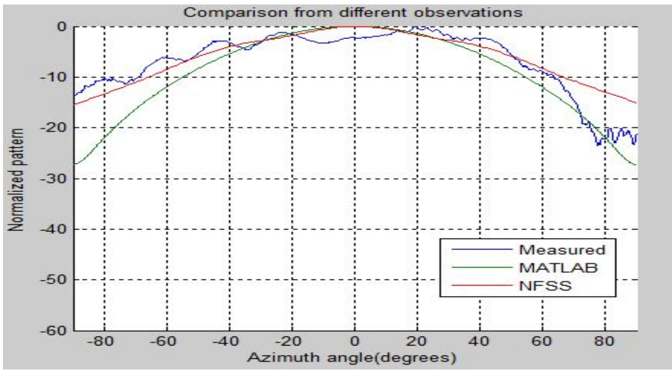


Figure 9: Comparisons of 4 element conformal array at 30^0 curvature result from Measured, MATLAB and HFSS tools

From figure 9 we can deduce that there is close similarity between MATLAB, HFSS and measured pattern result from antenna chamber for 4 element conformal at 30^0 curvature array except a small dip in the centre of the array. Figure 10 shows that the measured pattern for 4 element conformal antenna array at 40^0 curvature is close to simulated results from HFSS and MATLAB.

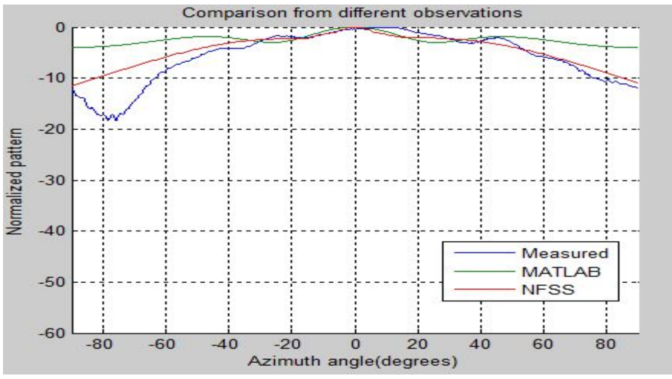


Figure 10: Comparisons of 4 element conformal array at 40^0 curvature result from Measured, MATLAB and HFSS tools

A comparison of the measured results with simulated results is shown in Table II.

Curvature	HFSS		Measured	
	Gain	BW	Gain	BW
Linear	9.9	25	7.3	26
30 deg	5.85	62	3.7	61
40deg	3.6	110	2.2	106

Table 2I Gain and Beamwidth of 4 Element Arrays(Measured)

The results for 8 element linear array is shown in figure 11. The measured results are close to simulated results from HFSS and MATLAB tools. Further to study the beam scanning capability of conformal array. Phase differences were introduced by the means of varied transmission line lengths to the patch element feeds as shown in Figure 12. The results of this array for a scan angle of 30 deg. is shown in Figure 13. The measured results shows good agreement with the fabricated results.

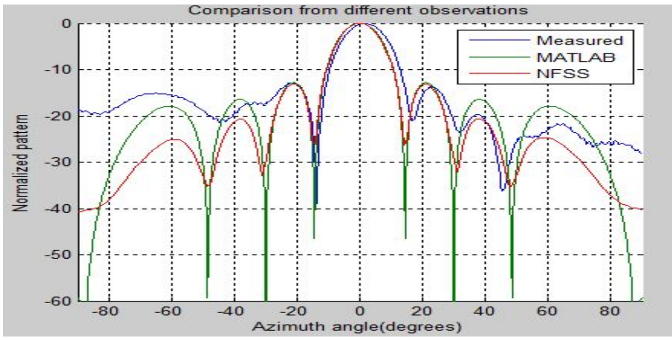


Figure 11: Comparisons of 8 element linear array result from Measured, MATLAB and HFSS tools

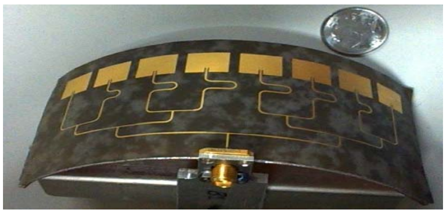


Figure 12: Photograph of 8-element phased array for scan angle-30 deg.

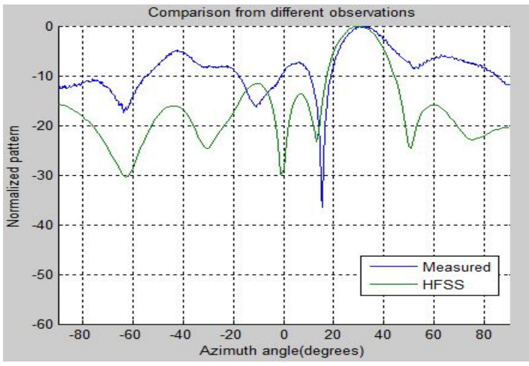


Figure 13: 8 element conformal array for a beam scan at 30^0

V. CONCLUSION

The studies shows that as the curvature of the arc conformal array increases the array beamwidth increases but with a trade off where gain reduces. The increased beamwidth can be very useful for wide beamwidth applications like Sidelobe Blanking(SLB) antenna and space applications. The curvature of the conformal antennas plays an important role in determining its properties. By choosing an appropriate curvature and making suitable phase corrections we can achieve beam scan from a conformal array. The results presented in this paper are promising for realising wide beamwidth antennas as well as electronically scanning conformal phased arrays.

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