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Design of Triangular Antenna Arrays conformal to both planer and cylindrical surface

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***Abstract*-In this paper ,the comprehensive study of equilateral triangular microstrip array conformal to both planer and cylindrical surface is presented for 2.4GHz. The triangular patch antenna configuration is chosen because it has the advantage of occupying less metalized area. In certain applications, desired antenna characteristics may be achieved with a single microstrip element. However, as in the case of conventional microwave antenna, characteristics such as high gain, beam scanning, or steering capability are possible only when discrete radiators are combined to form arrays. Specially in this paper single element, 1×2 and 1×4 are designed and simulated by HFSS-13. The effect of array on planer and cylindrical surface is studied. Better performance in gain , return loss and VSWR is observed for 1×4 conformal array as 13.78 dB,-48.69 dB, and 1.007 respectively. The proposed design can be used in many application including ISM band and WLAN.**

Keywords- Triangular patch array, Conformal array, Cylindrical surface, HFSS-13.

I. INTRODUCTION

Flexible, conformal microstrip antennas with high gain and low cost have broad applications in aerospace, point to point communications , operations (e.g., RFID) and medical industries [19]. Conformal antenna arrays can provide additional functionality and/or lower cost in many radar and communication applications. Examples could include the integration of conformal antennas into structures in aircraft and autos that could reduce air resistance and can provide wide range of coverage. Other possible purpose for using these antennas is making them less disturbing, i.e. less visible to the human eye since there are integrated on the structure. This attribute might be useful for urban or military environments. Conformal antennas can be almost any geometry, although the main structures investigated so far are cylindrical, spherical and conical. Antennas on singly curved surfaces are the simplest conformal antennas.

The conducting patch can take any shape, but rectangular and circular configurations are the most commonly used configurations. Among the shapes that attracted much attention lately is the triangular shaped patch antenna. One of the most attractive features of the ETPA is that, the area of the patch is nearly half as large as that of rectangular or square microstrip patch designed for the same frequency [4].However, the ETPA also shows narrow impedance bandwidth similar to other MSAs [7,8].

The single element antenna is generally with directivity of relatively low value and has a broad radiation pattern. Design with high directivity characteristics demands on antennas is a necessity in certain applications. Increase in directivity of antenna can be achieved by increase in the size of the antenna. An array can be an alternate to achieve the same. In order to determine its characteristics based on the array shape, element pattern, and array excitation among other factors that must be known to determine performance of conformal array antennas [2],[3],[6].

In this paper , the design of single element, 1×2 array and 1×4 array antennas are shown and analysis of such geometries for conformal structures are presented in detail. HFSS-13.0 was utilized to model and simulate these antennas.

II. THEORITICAL DESIGN OF SINGLE ELEMENT

The design parameters of triangular microstrip patch antenna include the side length of patch‘a’, printed on a substrate of thickness ‘h’.The resonant frequency may be determined with better accuracy, if ‘ε_r’and ,‘**a**’ are replaced by effective dielectric constant ‘ε_{eff}’ and ‘a_{eff}’ and resonating frequency **fr** is calculated using following formula [1],[7],[10].

$$\varepsilon_{r_{eff}} = \frac{\varepsilon_r+1}{2} + \frac{[\varepsilon_r-1]}{4}\,[1+12\frac{h}{a}]^{-1/2}$$

$$a_{eff} = a + \frac{h}{\sqrt{\varepsilon_r}}$$

$$fr = \frac{c}{2a_{eff}\sqrt{\varepsilon_{reff}}}$$

The substrate used in this model is the RT/Duroid 5800 (tm) with a dielectric constant of 2.2 , side length of 54.9 mm and thickness of 1.6 mm. The Figure 1 shows the triangular patch with its dimension and patch bent to cylindrical substrate shown in Figure 2. Microstrip elements are uniformly located on a cylindrical surface of radius equals to 3 $ʎ_0$, so bend effect less to the resonating frequency of conformal antenna. As operating frequency is 2.4 GHz and lambda is 125 mm, hence radius is chosen as 375mm.

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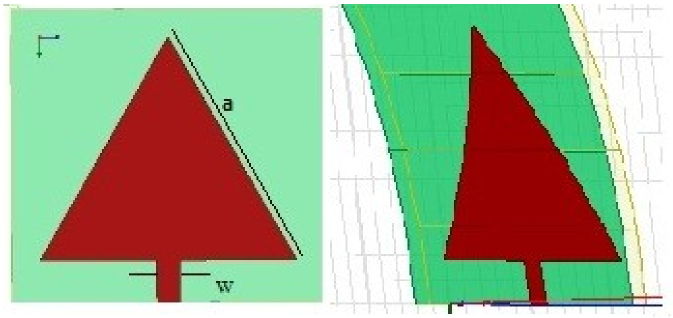

Figure 1: Geometry of patch antenna a) Triangular in planer: b) Triangular Conformal antenna; with dimensions (in mm): a=54.9,w= 4.82.

This section outlines the result of single element using HFSS 13. The Figure 2 shows S11 curve for of planer yields a minimum of -36.86 dB at frequency 2.1944 GHz, whereas conformal patch resonates at 2.3116GHz of -46dB. Return loss and VSWR improves for conformal patch.

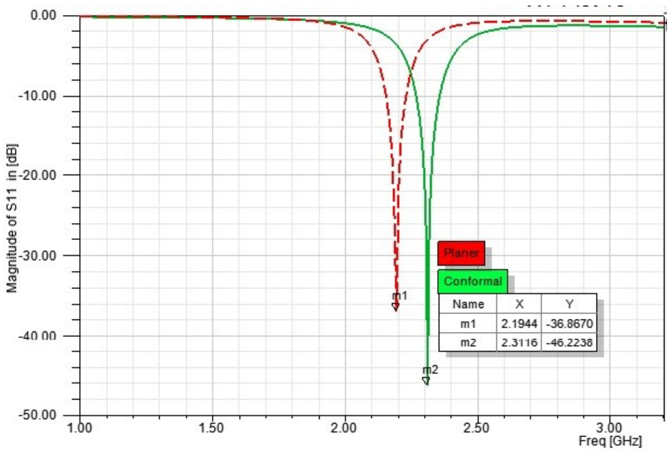

Figure 2 : Simulated reflection coefficient (in dB) of designs shown in Figure 1.

III. 1×2 ARRAY

The elements of an array may be spatially distributed to form a linear, planar, or volume array. A linear array consists of elements located finite distances apart along a straight line. The network is designed to realize impedance matching by using quarter wavelength impedance transformers.

Figure 3 shows the configuration of 1×2 planer ETPA and non planer array which should increase an increase in gain and directivity. The patches are separated by ʎ$_0$/2, The network is designed to realize impedance matching by using quarter wavelength impedance transformers [17]. The network has a center line of 100 which is fed at its center by a 50Ω transmission line. The impedance is transformed to 50Ω through a 70:7 quarter wavelength line.

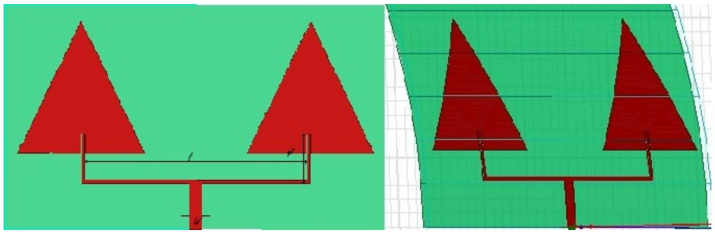

Figure 3: Geometry of 1×2 array a) Triangular in planer: b) Triangular Conformal antenna; with dimensions (in mm): l=96,W= 4.89, Y1=18.

The antenna array was first simulated for planer and subsequent simulation was performed for the cylindrical surface having radius 375mm. As the performance of antenna for conformal surface degrade as bending increases [2]. The comparison of S_{11} and VSWR which shows improvement of return loss as -47.86 dB for conformal array at 2.32GHz whereas it is -31.1358 dB at 2.31 GHz in case of planer array. As graph shows increase in array size results in significant changes in frequency in conformal to planar antenna due to effect of curvature and mutual coupling on account of inter element spacing[6].

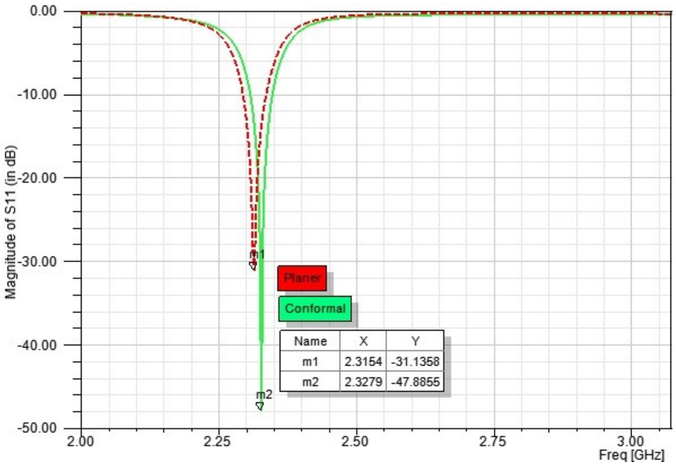

Figure 4 : Simulated reflection coefficient (in dB) of designs shown in Figure 3.

IV. 1×4 ARRAY

The next step in our modeling investigation was to increase the number of radiating elements from 2 to 4 to understand the trends for a larger array size (which should result in an increase in the gain and directivity of an antenna array). Figure 5 shows the dimensions of the 1×4 array layout in planer. Distance between patches is ʎ$_0$/2, l =201.2 mm , l_0 =185mm and l1 =23.1mm. The array was designed for same operating frequency of 2.4 GHz. The feeding network was designed for 50 Ω at center , the dimensions of quarter wave transformer are based on calculations.

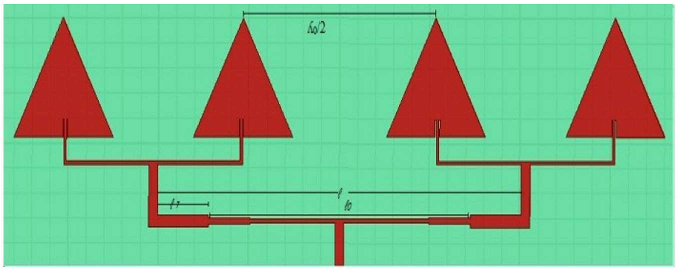

Figure 5: Geometry of 1×4 Triangular array in planer.

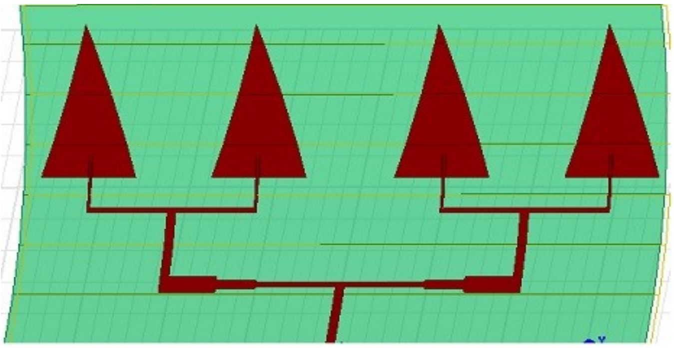

Figure 6: Geometry of 1×4 Triangular array conformal of cylindrical surface.

Figure 6 shows array in bending curve of radius of 375 mm i.e. 3 ʎ$_{0}$. The Simulation result of both design are shown in Figure 7 . It can be seen that S_{11} is -37.4264 dB at resonating frequency 2.11 GHz and -48.69 dB at 2.29GHz for 1×4 planer and conformal array respectively.

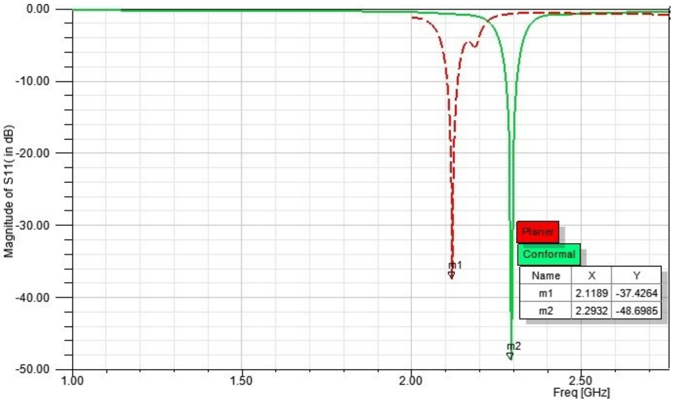

Figure 7 : Simulated reflection coefficient (in dB) of 1×4 array in planer and conformal.

V. COMPARISION AND RESULT ANALYSIS

Table 1 shows the simulated result of single element, 1×2 array ,1×4 array in planer and conformal. The gain is best in 1×4 ETPA, as gain increases as number of element increases. Reflection coefficient is best in conformal array as -48.69 dB and VSWR as 1.007 .The improved Return loss, VSWR as shown in table with the advantage for conformal antenna over planer patch antenna.

Table 1: Comparison between planer and conformal antenna arrays.

No. of Elements	S_{11}(dB)		VSWR		Gain (dB)	
	Planer	Con.	Planer	Con.	Planer	Con.
Single	-36.86	-46.22	1.029	1.009	7.60	7.65
1×2	-31.13	-47.86	1.057	1.008	10.70	10.82
1×4	-37.42	-48.69	1.027	1.007	13.29	13.78

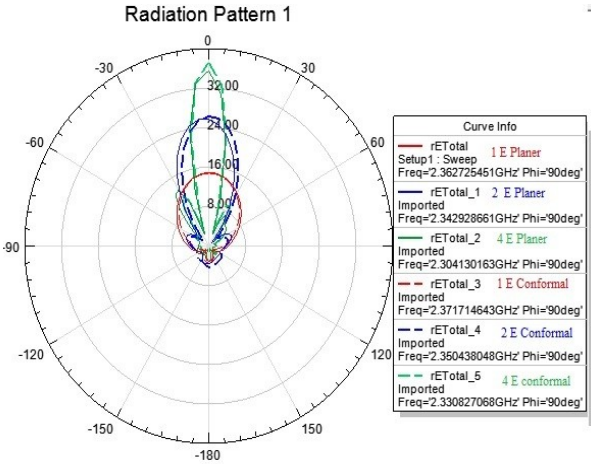

Figure 8: Radiation Pattern for Single Element, 1×2, 1×4 in Planer and Conformal.

As due to mutual coupling on account of inter element spacing the frequency of array shifts from single element. The side lobe level is increasing as the number of element increased as shown in radiation pattern of all arrays in planer and conformal as shown in Figure 8.

As shown in the table, the gain obtained from planer are very close to those for conformal antenna. But as the bending of cylindrical surface increases there is reduction in performance and shifts in lower frequency [2]. Depending on the particular application, this performance may be tolerable. The reason for the diminishing performance of bent arrays are attributed to ohmic losses, mismatch losses, mutual coupling effects among patches irregular inter-spacing.

More and more conformal antennas are used in communication and navigation technologies. The possibility, as its name says, of conforming them in a determined shapes makes them attractive for aircraft, automobiles or ships, where aerodynamics may well be improved by adjusting the antennas to the contour of the vehicles.

The most outstanding drawback of conformal antennas is the increased complexity and cost in manufacturing. The curvature effects on resonating frequency.

VI. CONCLUSION

In this article, single element , 1×2 and 1×4 microstrip triangular array were designed and simulated at 2.4 GHz for different planer and conformal geometries. Conformal are bent to cylindrical surface of 3ʎ$_{0.}$ These initial simulation results will be used to guide the development of fabricated arrays of different shapes on flexible substrates. This work provides the opportunity of continuing the research on the toroidal and spherical geometries. In addition, array configurations in this new structure might be interesting to study, e.g. for beam forming in broad coverage. A deeper investigation would be to study the theoretical methods of analysis and design on this type of antenna.

Array configurations of conformal antennas would be the next step for the general conformal antenna study. Further investigation on conformal antenna arrays might reveal additional advantages over planar ones.

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