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Performance Analysis of Microstrip Conformal Antenna Array and Effect of Mutual Coupling for Different Curvature

Prashansha Kumari
Department of Electronics& Communication Engineering
DIT University, Dehradun
UK, India

Brajlata Chauhan
Department of Electronics& Communication Engineering
DIT University, Dehradun
UK, India

Sandip Vijay
Department of Electronics& Communication Engineering
DIT University, Dehradun
UK, India

ABSTRACT
This geometry can offer certain characteristics that can't be achieve by planner antenna. Antenna is design to function in 2.4 GHz wireless radio band. This work present performance of 4-element conformal antenna array for cylindrical surface and observe effect of mutual coupling between patch. In this, angle is preserved to conform the shape to reduce extra drag. The radius of cylinder is considered to be atleast one quarter wavelength or slightly more. The simulated results shows its resonant frequency is not affected with change in curvature however the radiation patterns are significantly affected more in elevation direction and less in azimuth. Simulations has been carried on CST software.

Keywords
Conformal antenna array, CST studio suite, mutual coupling, microstrip patch antenna.

1. INTRODUCTION
Conformal antenna used in many application like satellite communication, aircrafts and military airborne surveillance radars that required an antenna to operate on a curved surface [1-8]. Conformal antenna is built so that it can integrated easily with the structure without causing any extra drag.
Conformal antenna can be define as an antenna that conforms to prescribed shape. The shape is determined by consideration other than electromagnetic for example aerodynamic or hydrodynamic. The microstrip conformal antenna having advantages like simple structure easy manufacture, low coast, convenient integration makes the antenna less disturbing, less visible to the human eye. However there is also some disadvantages like lower efficiency and narrow bandwidth due to surface waves, feeding loss, dielectric loss. Hence to design antenna for prescribed shape without reducing performance is our new challenge [9-13].
Antenna array is known as conformal array when the elements of antenna are conformed on the surface like cylinder, sphere, a cone or other similar without causing extra drag. Most of the real world can be approximated to the cylindrical shape hence analysis of the cylindrical microstrip patch antenna is preferred here. Antenna having single element generally having relatively low directivity and broad radiation pattern. Some application required high directivity antenna since high directivity can achieved by increasing the size of antenna or increasing the number of element in antenna[14-20].
Conformal shape can be slightly curved, singly curved, doubly curved and cylindrical array. The slightly curved antenna behaves more or less as planner antenna. The design are roughly the same. To make general statement for the other type antenna are difficult because of so different requirement like dimension, shape, element types etc. While designing the element in the antenna array we need to give importance to aspect such as effects of mutual coupling between antennas. Grating lobes created due to the mutual coupling ant it suppressed by the evenly distribution of element over antenna surface or obtaining high element density. Roughly the spacing between the elements is half wavelength[21-24].

2. CONFORMAL MAPPING
Conformal mapping technique is very simple and close approximation besides involving simpler function rather than tiresome integrals equations are involved in other techniques. The conformal mapping of a boundary is between the dielectrics which is valid since it hold the angle of refraction of electric field at the boundaries.

Assume a complex function given below for mapping:

$$f(z) = u(x, y) + iv(x + y)$$

Which gives mapping of its domain D in the complex z-plane into the complex w-plane. Consider that

$$w = f(z) = z^2$$

$$u = Re(z^2) = x^2 - y^2$$

$$v = Im(z^2) = 2xy$$

Here the line x=c is constant and y=k= is constant and mapped onto the Parabolas opens to the left and right

$$v^2 = 4c^2(c^2 - u)$$

$$v^2 = 4k^2(k^2 - u)$$

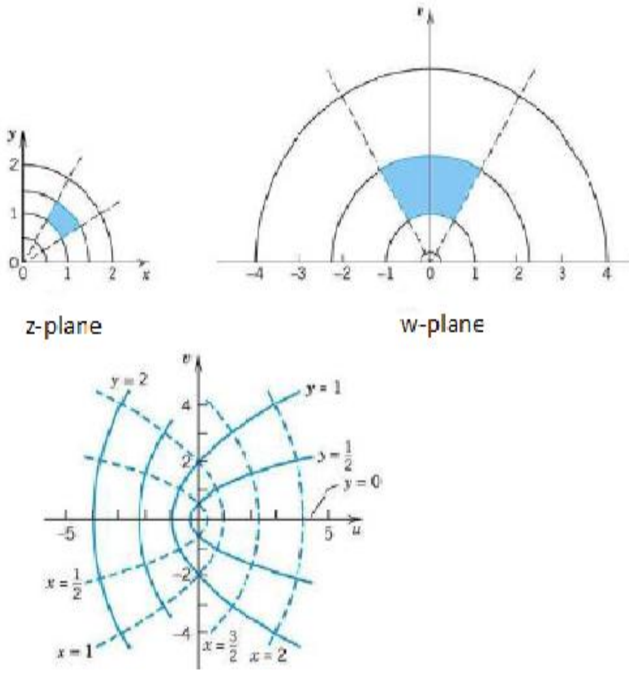


Fig.1. Mapping onto a prescribed shape

A mapping of w-plane is function of z-plane except critical point that is at which the derivative f' become zero. Consider that, w=f (z) and the angle between two intersecting curves is α and angle lies between 0 and π (0≤α≤π) as shown in fig. 2. Assume that curve C having

$z(t) = x(t) + iy(t)$; in domain of f(z)

$\dot{z}(t) = \frac{dz}{dt} = \dot{x}(t) + i\dot{y}(t)$; *is tangent to C*

We can say that conformal for C is, B=w=f (z (t))

According to chain rule, $\dot{w}(t) = f'(z(t))\dot{z}(t)$

Hence the tangent direction of B is $arg\dot{w} = argf' + arg\dot{z}$

Where $arg\dot{z}$ gives direction of C.

From figure 2(a) we can say that the mapping rotates in all direction at appoint z0 in the domain of analytic of function f through the some angle argf, which exist till f"(z0)n eq0.

$w = z^n$, $n = 2.3 \ldots \ldots$ *is conformal except at* $z = 0$

Where $w' = nz^{n-1} = 0$, generally n the angle at 0 are multiplied by factor n while mapping hence 0≤θ≤π/n is mapped by z^n onto upper half plane $v \geq 0$.

Conformality is the most important geometric property of analytic functions and give possibility of a geometric approach to complex analysis.

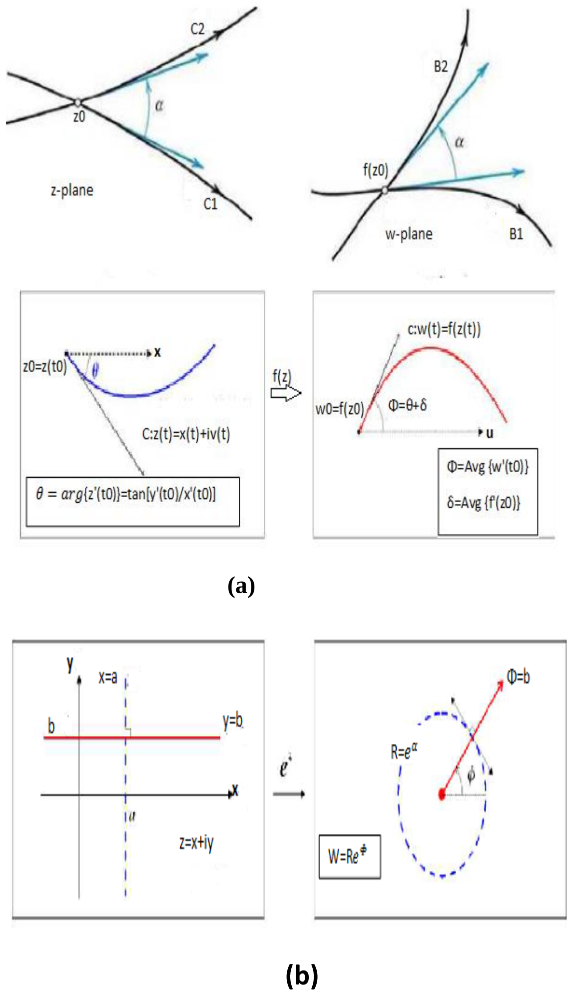


Fig.2. conformal mapping onto a prescribed shape

3. FOUR-ELEMENT CONFORMAL ANTENNA ARRAY DESIGN

The elements of the array consisted of individual microstrip patches which is design to operate at 2.4 GHz frequency. Each patch was printed on a single grounded Rogers 5880 RT/duroid substrate (Ɛr=2.2, tan δ=0.00009) [34] with a thickness of 1.575mm. The radius of cylinder used in simulation is 0.24λand0.32λ.

3.1 Single Element Antenna Structure:

The design of the planner rectangular patch antenna is shown in Figure 3(a). The dimensions of the entire microstrip patch are given in Table 1. Figure 3(b) shows the return loss response of the patch element antenna. The design procedure are as follows [25-28].

FORMULATIONS:

A. Calculation of Width

The width of microstrip antenna is given by

$$w = \frac{C}{2\, fo \sqrt{\left(\frac{\varepsilon r + 1}{2}\right)}}$$

B. Calculation of Effective dielectric constant :

$$\varepsilon reff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{1}{2}}$$

C. Calculation of Length Extension(ΔL) :

$$\Delta L = 0.412\frac{(\varepsilon reff \pm 0.3)(\frac{w}{h}+0.264)}{(\varepsilon reff - 0.258)(\frac{w}{h}+0.8)}$$

D. Calculation of Actual Length (L):

The actual length of radiating patch obtained by:

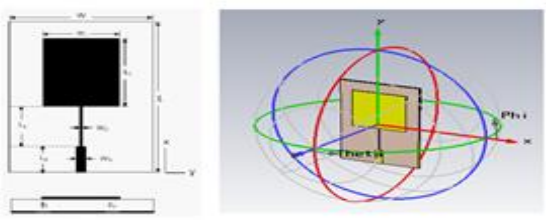
$$Leff = L - 2\Delta L \;\; \& \;\; Leff = \frac{c}{2fo\sqrt{\varepsilon reff}}$$

E. Calculation of Ground dimension(Lg,Wg):

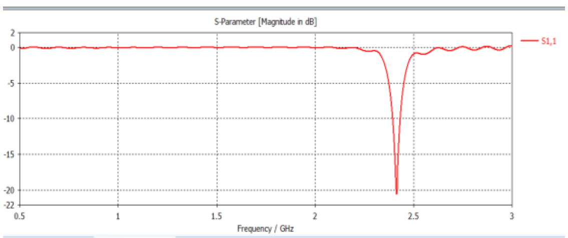
$$Lg = 6h + L \text{ and } Wg = 6h + W$$

Table 1: Antenna dimensions in mm.

L	W	L1	W1
60	88	41.08	39.03
L2	W2	L3	W3
0.72	24.05	4.84	15



(a)



(b)

Figure 3: (a) The layout of single element patch antenna structure, and (b) is its return loss *S*11 (dB) response for single element patch antenna

3.2 The Proposed Conformal Antenna Array Structure

The elements of the array consisted of individual microstrip patch with spacing of 0.24λ and 0.32λ. Patch elements were equally spaced on cylindrical substrate of 1.57mm Rogers 5880 RT/duroid. Conductive material for proposed design is 0.7mm thick copper. The height of cylinder is 90mm and radius of the cylinder should be atleast one quarter wavelength. The 3D view of 4-element conformal antenna is shown in fig.4.

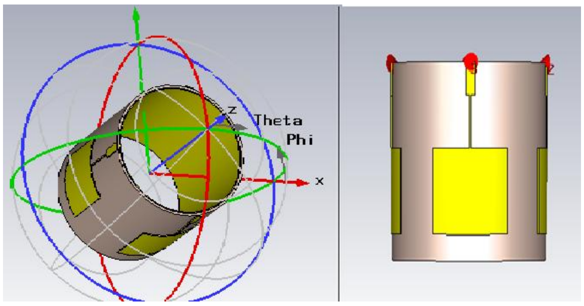
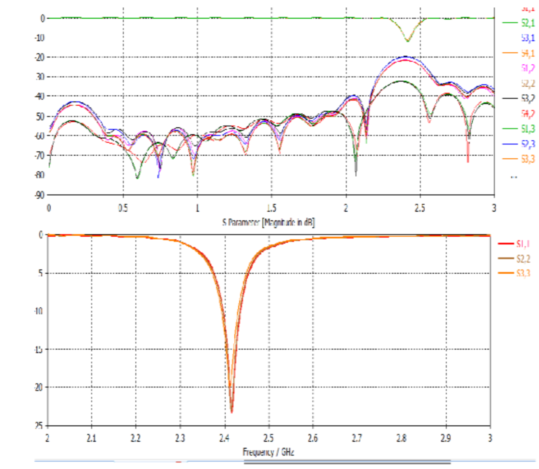


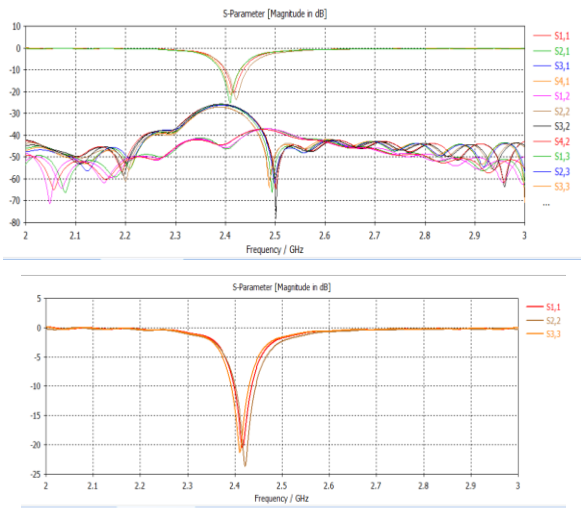
Figure 4: Geometry of proposed antenna.

4. S-PARAMETER AND RADIATION PATTERN RESULTS OBTAINED BY SIMULATION

The result shows that the resonant frequency is not affected by curvature however the radiation patterns are significantly affected as shown in fig.5 and fig.6.The radiation pattern in the elevation direction is strongly dependent on the cylinder radius but azimuth angles much less dependent on the cylinder radius**.**

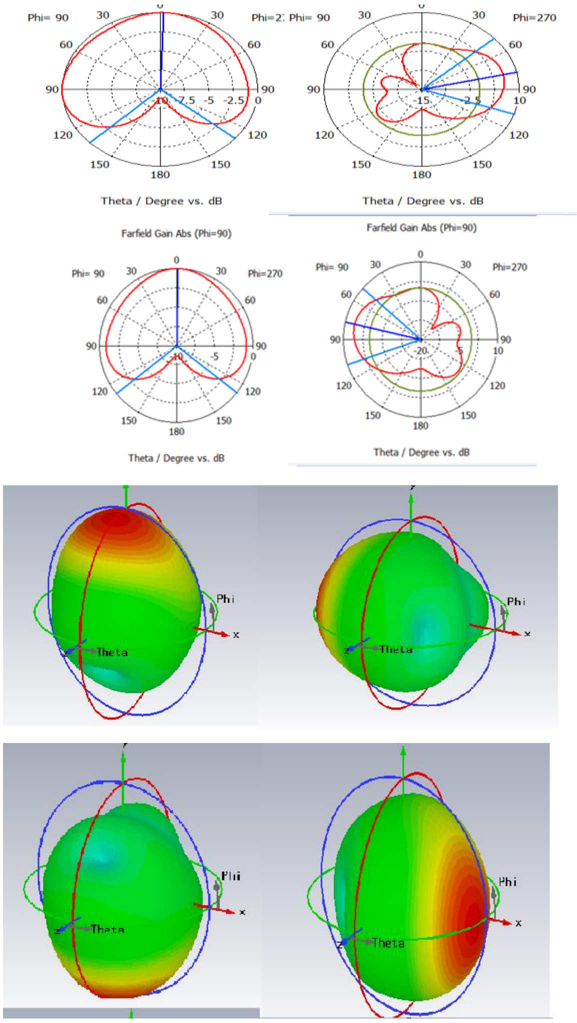


(a)

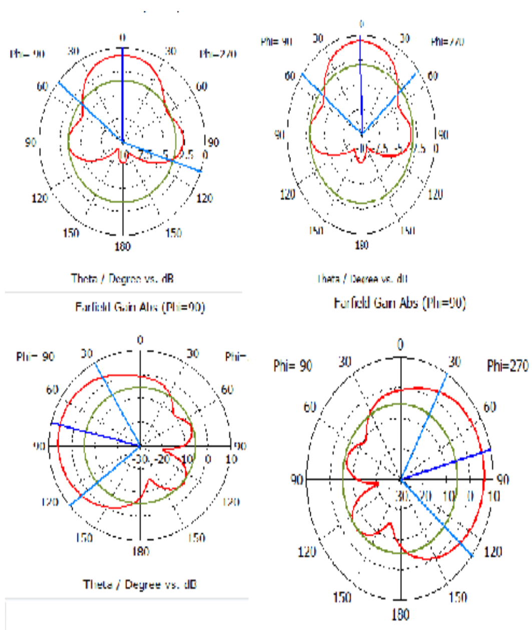


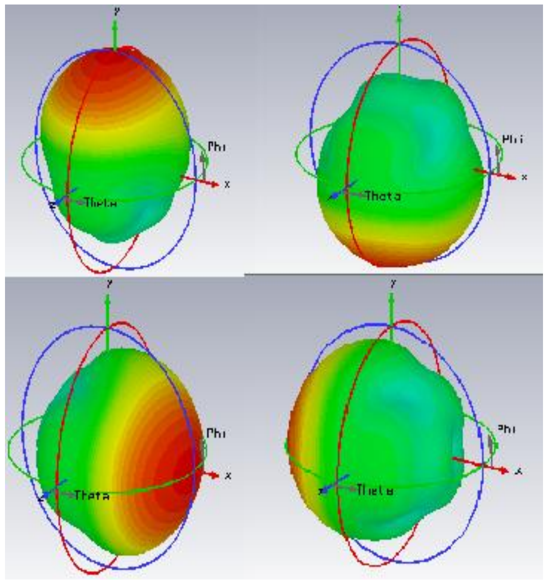
(b)

Figure 5: Simulated coupling of the 4-element array conformed on cylinders with radii of (a) 30mm and (b) 40mm.



(a)





(b)

Figure 5: Radiation patterns: (a) for element in cylindrical array, the radius of cylinder is R = 30mm and (b) radius of cylinder is *R* = 40mm

Table 2: Gain and Directivity for elements in cylindrical array (a) for the radius of cylinder is R = 30mm and (b) radius of cylinder is *R* = 40mm

	Port 1	Port 2	Port3	Port4
Gain	6.328db	6.159db	6.128db	6.338db
Directivity	6.722dbi	6.541dbi	6.493dbi	6.724dbi

(a)

	Port 1	Port 2	Port3	Port4
Gain	6.45db	6.135db	6.11db	6.03db
Directivity	6.45dbi	6.625dbi	6.420dbi	6.46dbi

(b)

5. CONCLUSION

For the designing of the conformal microstrip antenna on a cylindrical surface it is important to study the effect of mutual coupling. In this paper we study with the inter element space between the element is 0.24λand 0.32λ. When the cylindrical radius is more than one quarter wavelength then only acceptable mutual can be obtained. The element pattern of antenna get rises due to the mutual coupling in array. This paper also conclude the detailed performance analysis of S-parameter, gain, directivity , radiation pattern in θ and Φ plane for 4-element conformal antenna array as shown in table 2. Resonant frequency of antenna does not affected the radius of cylinder while ration pattern is affected. This type of antenna suitable for radar application and wireless communication system.

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7. AUTHOR PROFILE

Prashansha kumari was born in 1991. She received her B.E degree in Electronics and Communication Visvesvaraya Technology University Bangalore in 2013, India and also pursuing her M.Tech from DITU Dehradun Uttrakhand. Her research interest includes design and characterization of implantable microstrip patch antenna and conformal antenna.

Mrs. Brajlata Chauhan received her Master degree in Digital communication from Uttrakhand technical University Dehradun Uttrakhand in 2010, India and also pursuing her PhD from UTU Dehradun UK. She is working in Dehradun Institute of Technology, Dehradun as AP. A life member of Institute of Electronics and Telecommunication Engineers India. She is having teaching experience of 11 years in Engineering Institutions.

Sandip Vijay received B.Sc. (Engg.) from PIT Patna (Erstwhile Magadha University) in 1998 M.Tech. (Electronics& Comm. Engg.) In 2000, the member of IEEE (USA), NSBE(USA), IANEG (USA), ISOC (USA),Life Member of ISTE(INDIA) has published over Eighty research papers in national and international journals/conferences and IEEE Proceeding publication in field of Wireless & Digital Communication Network, and supervised more than 40 projects/dissertation of M.Tech. & B.Tech. Students. He started his career as R & D Engineer in Dell Computers in the field of Quality Assurance Engineer then joined teaching profession as a Lecturer and later on promoted as Asst.Professor (EC) in GEIT, Uttranchal Technical University, (Now Graphic Era University). He has successfully completed major research projects independently by VSI & DA-IICT, Gandhi Nagar, in the field of VLSI Design. He finished his Doctorate in 2011 from I.I.T. Roorkee in the field of Wireless Computing under Ministry of HRD, Government of India fellowship. Currently working as Associate Professor in Department of ECE & AEI at Dehradun Institute of Technology (DIT), an autonomous college of Uttrakhand Technical University, Dehradun (Uttrakhand). Total Publication till Date: 82