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DESIGN AND IMPLEMENTATION OF CONFORMAL MICROSTRIP PATCH ANTENNA FOR X-BAND APPLICATIONS

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Abstract:

In this paper, conformal rhombic microstrip patch antenna for X-band application (8GHz to 12GHz) is depicted using software analysis. The key benefits and shortcomings of a conformal microstrip patch antenna are being familiarized through this paper. Here we are designing non-planar antenna with cylindrical surface having radius of curvatures R1=15mm, R2=30mm and R3=45mm and comparison of planar and non-planar antenna design will be undertaken. Microstrip feedline technique is utilised for ease of impedance matching. The antenna designing and analysis is carried out on High Frequency Structure Simulator (HFSS). The consequences of bending due to conformability of patch over various cylindrical surfaces are calculated. Radiation pattern (E-field and H field), reflection coefficient (S11), peak gain (dB) and antenna efficiency are examined as a function of radius.

KEYWORDS: Microstrip patch antenna, Conformality, Resonant Frequency (F_r), radius of curvature, reflection coefficient, peak gain, antenna efficiency.

I. INTRODUCTION

Microstrip patch antennas have been extensively studied and utilised in recent decades for multiple applications. The main reasons are its weightlessness, low silhouette, low cost, improved gain and conformability to various curved surfaces due to fabrication using various substrates [1]. Planner microstrip patch antennas have been extensively considered in varied fields and the models used to analyse this type of antenna have touched greater heights with some kind of maturity [1]. Conformal microstrip antennas are critical in many applications such as wireless mobile communication, aircraft, missiles, military and commercial radars and constellation satellites [2]. An improved technique for producing uniform cylindrical structures would be to spool the physical material into a cylindrical shape [2].

II. ANTENNA DESIGN

Conformal microstrip patch antenna on various cylindrical shapes for X-band application (8GHz to 12GHz) is designed and analysed in this paper. Fig.1 shows the sketch top view, side view and bottom view of the planar rhombus microstrip patch antenna. Fig.2 shows the amalgamation of patch over the Planar, cylindrical shapes of radius of curvature R1=15mm, R2=30mm and R3=45mm. The antenna has been designed on a Rogers RT Duroid 5880 (ε_r = 2.2, tanδ = 0.0009) substrate with dimension (LxW) (15x12)mm^2 and thickness (S) of about 0.25mm. The dimensions of the ground plane for the planar microstrip patch antenna (G1xG2) is (15x5.8)mm^2. The design is a rhombus patch with edge length (A) of 6.5mm and (B) 3mm and overlapping length of microstrip feedline (C) being 0.8mm. The microstrip feedline technique is utilised to stimulate the antenna and gives an ease on impedance matching and fabrication. The designed feed gap (F2) and the length (F1) are attuned to 0.8mm and 6mm.

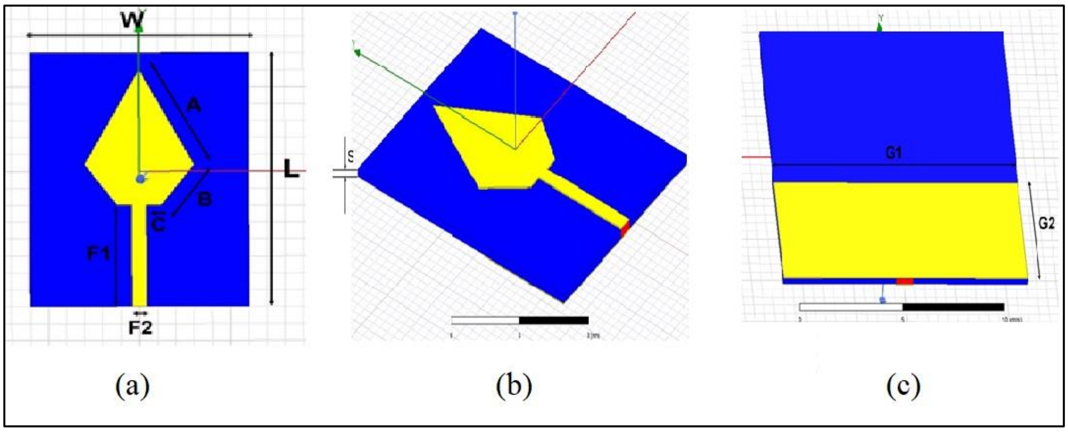

Fig. 1 Antenna Design (a) Front view, (b) Side View, (c) Bottom View

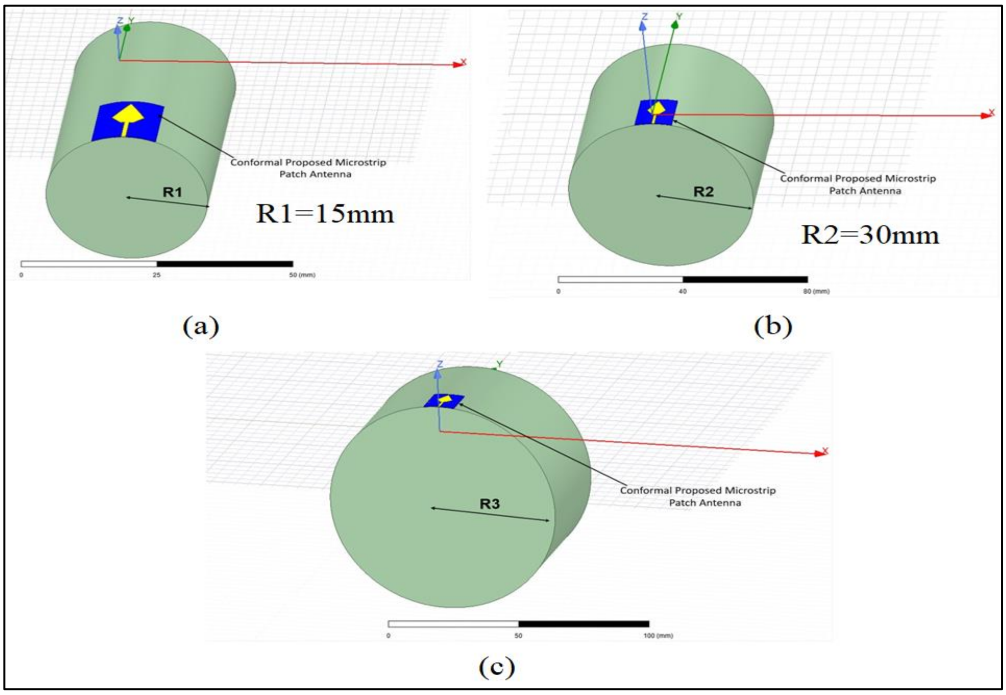

Fig. 2 Integration of Patch on cylindrical surface with radius of curvature
(a) R1=15mm, (b) R2=30mm, (c) R3=45mm

III. **RESULT**

The planar rhombic microstrip patch is placed on various cylindrical surfaces which shows the variations along the radius of the cylindrical shapes. The patch shows no curvature bending effect when positioned on the two-dimensional shape. With the introduction of nonplanar surfaces, the patch shows curvature bending effect along the direction of observation. Due to conformality of the microstrip patch along the radius of different cylindrical surfaces, the effect of change can be observed on the parameters such as reflection coefficient, resonant frequency, peak gain, radiation pattern and antenna efficiency.

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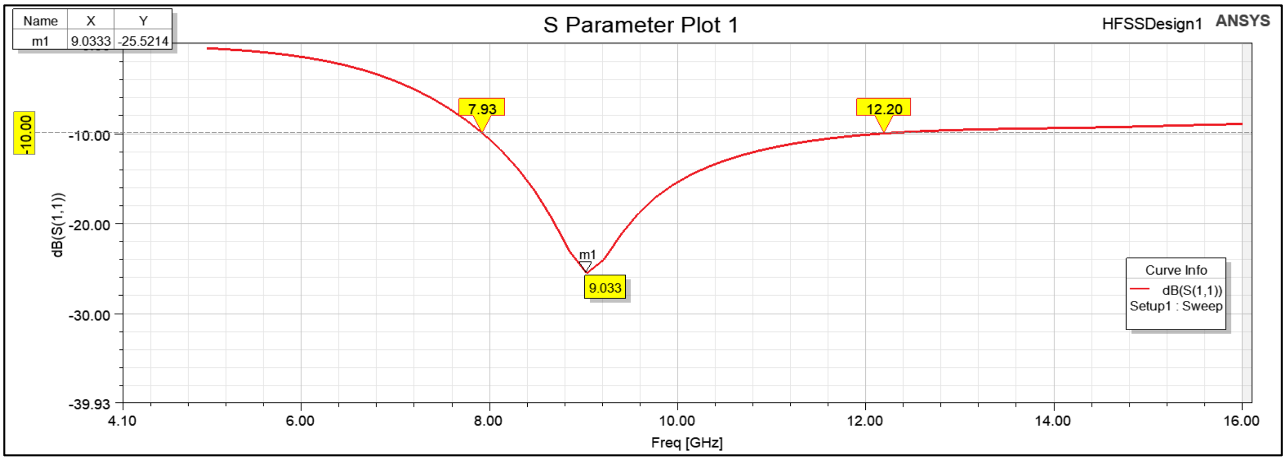
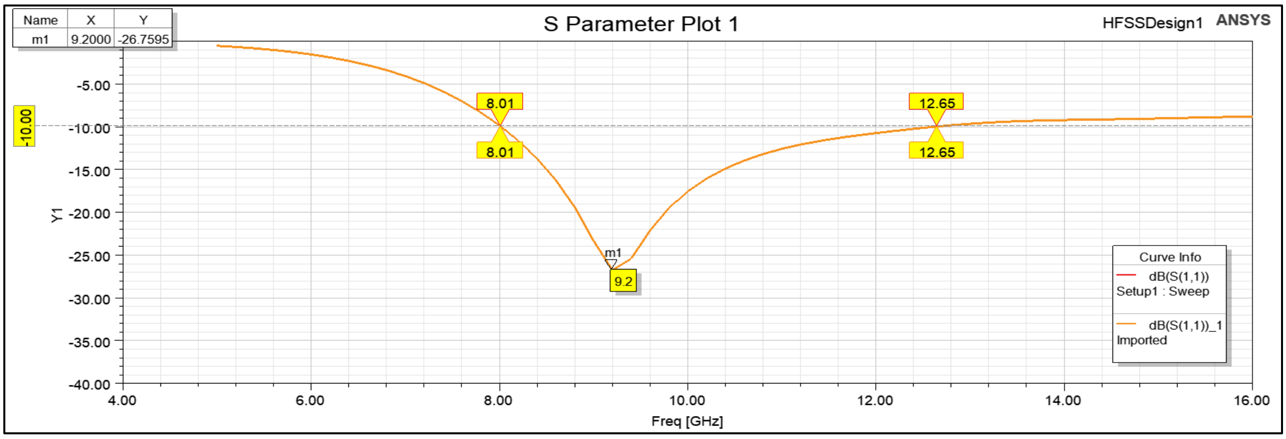
IV. EFFECT OF CURVATURE ON REFLECTION COEFFICIENT



(a)



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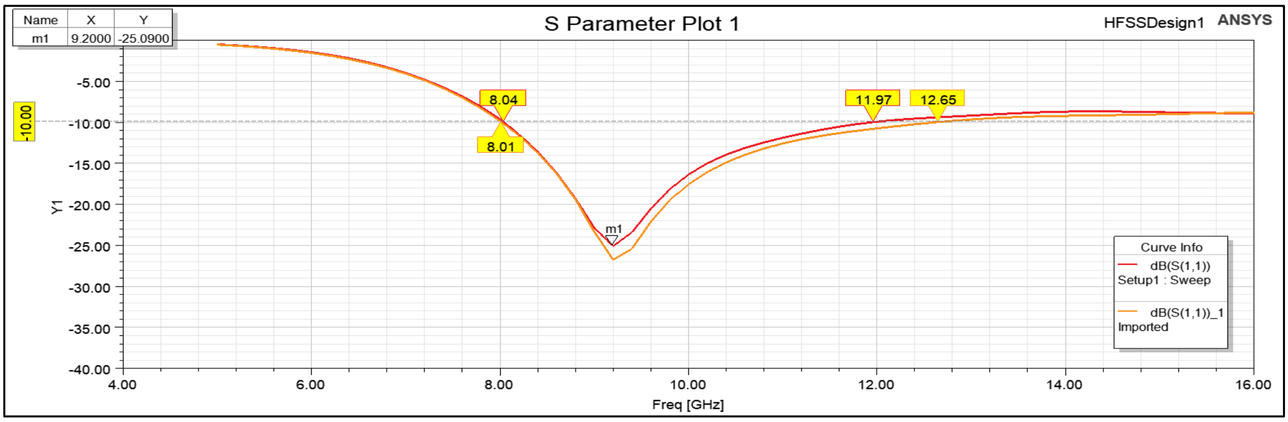

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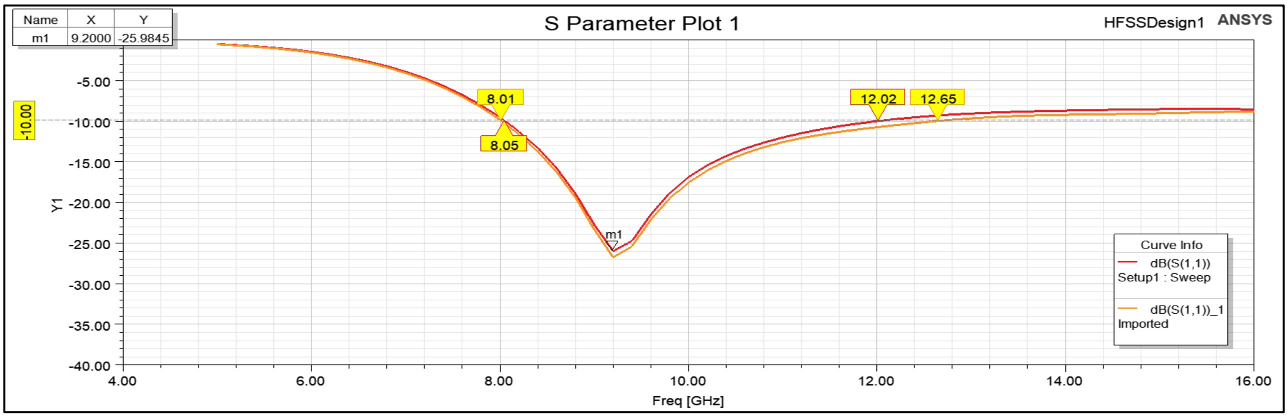
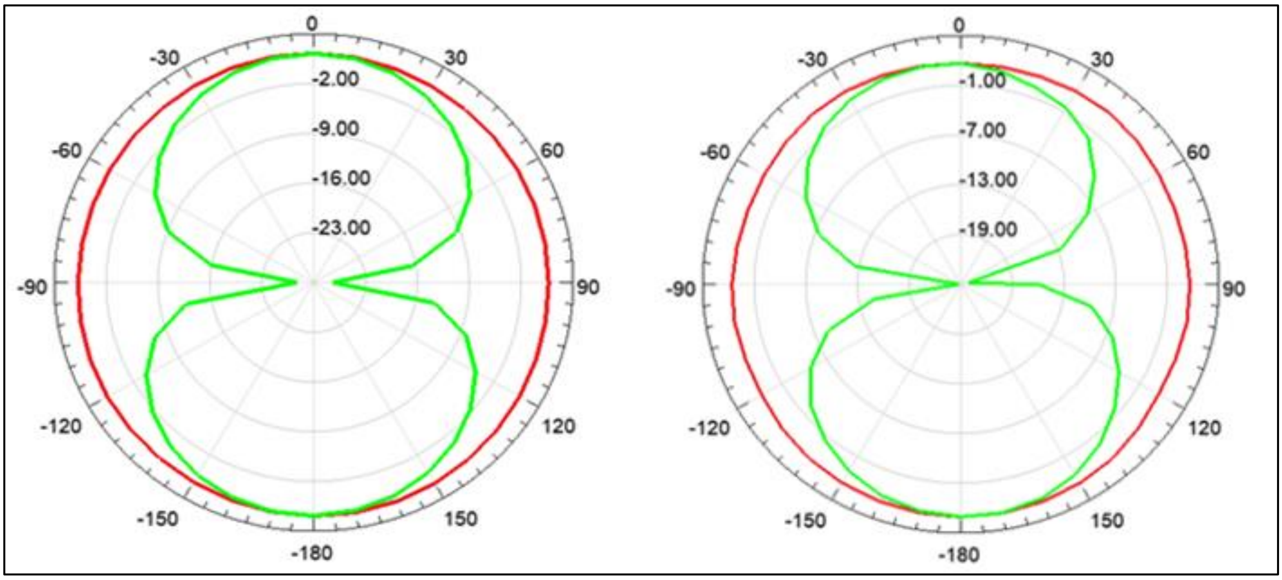


(d)

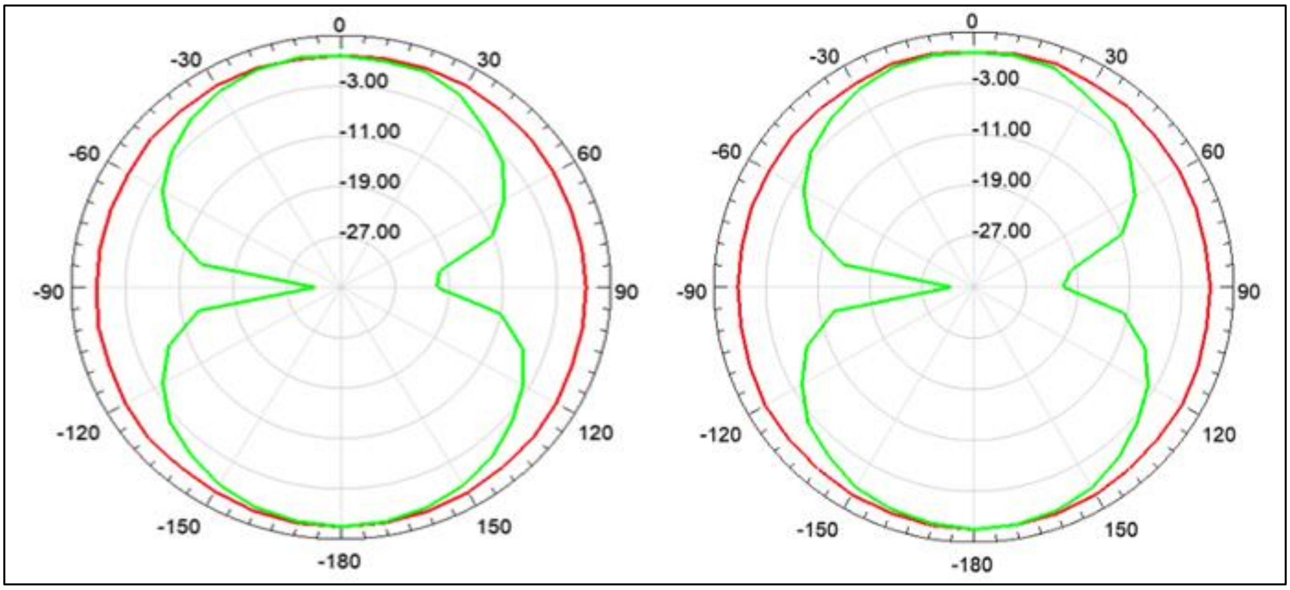
Fig. 3 Reflection Coefficient (S11) for two-dimensional and nonplanar cylindrical conformal microstrip patch antennas (a) Planar Antenna, (b) R1=15mm, (c) R2=30mm, (d) R3=45mm

Fig. 3, depicts the reflection coefficient (S11) for the two-dimensional and cylindrical microstrip patch antennas. It has been observed, that there is an infinitesimal small amount of shift in resonant frequency when the patch is conformed on nonplanar cylindrical surfaces [3]–[8]. For cylindrical surface, there is an upward shift in the resonant frequency. It is also observed that the minimum S11 at resonant frequency is almost similar for planar and nonplanar antenna. Analysis results show that the bandwidth of the planar and nonplanar antenna is approximately same with minor reduction with increase in cylindrical radius [9].

V. EFFECT OF CURVATURE ON RADIATION PATTERN



(a) (b)

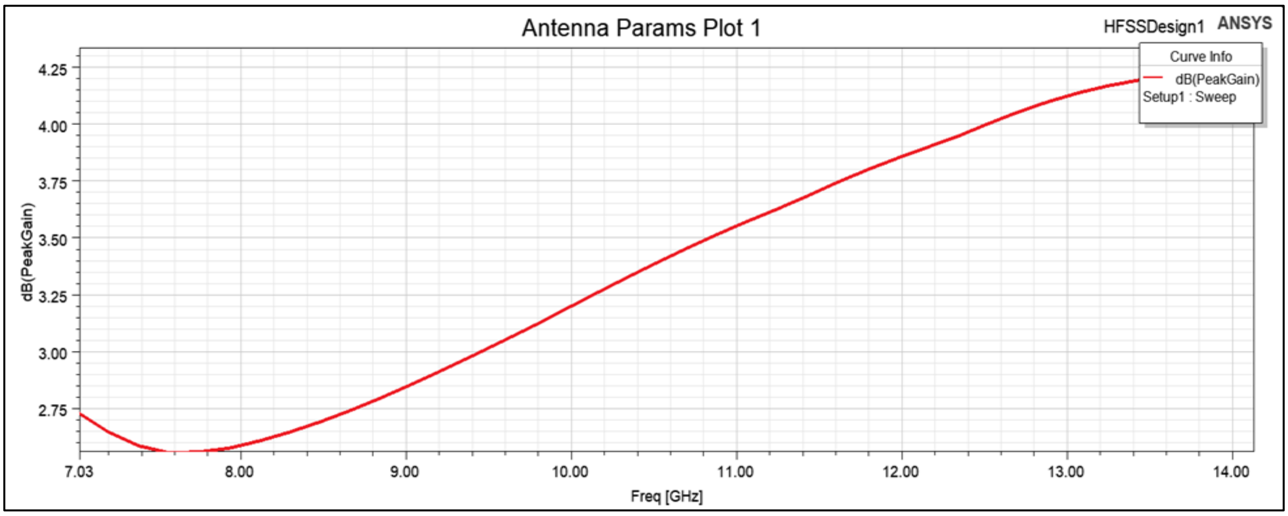


(c) (d)

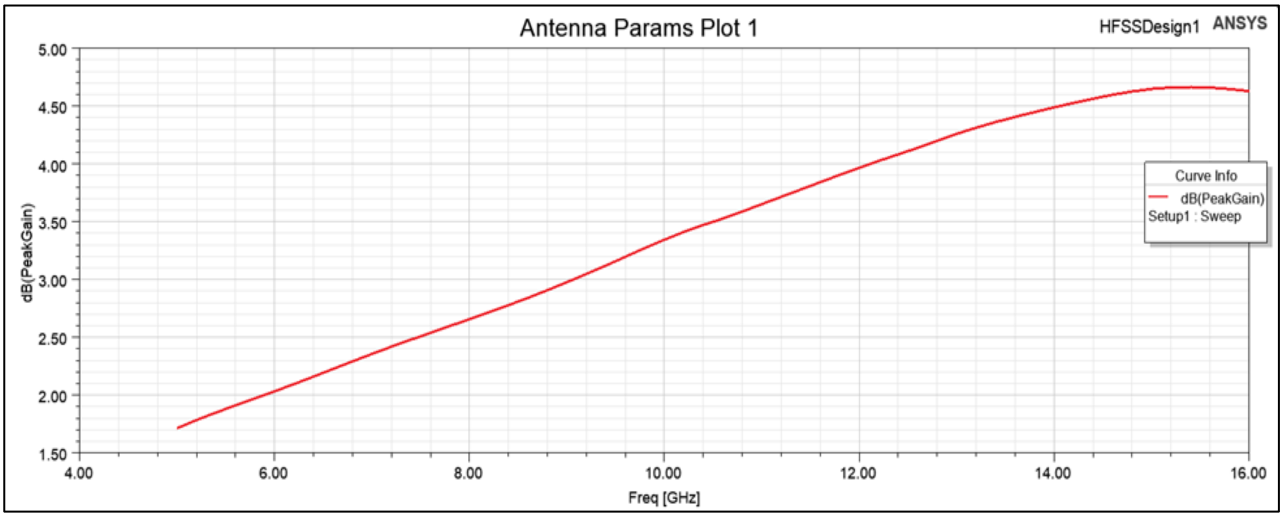
Fig. 4 Radiation pattern of
(a) Two-dimensional microstrip patch antenna, (b) Conformal MPA with R1=15mm, (c) Conformal MPA with R2=30mm, (d) Conformal MPA with R3=45mm

Fig. 4 depicts the radiation patterns in the E-plane and H-plane for the planar and different nonplanar conformal microstrip patch antennas. It is observed that antenna is an omni-directional antenna with magnetic field (H) in horizontal plane (azimuth plane, phi = 0 Deg) being perfectly circle i.e., the pattern magnitude is nominally constant in azimuth plane containing maximum directivity and electric field (E) in vertical plane (elevation plane, phi = 90 Deg).

VI. EFFECT OF CURVATURE ON GAIN



(a)



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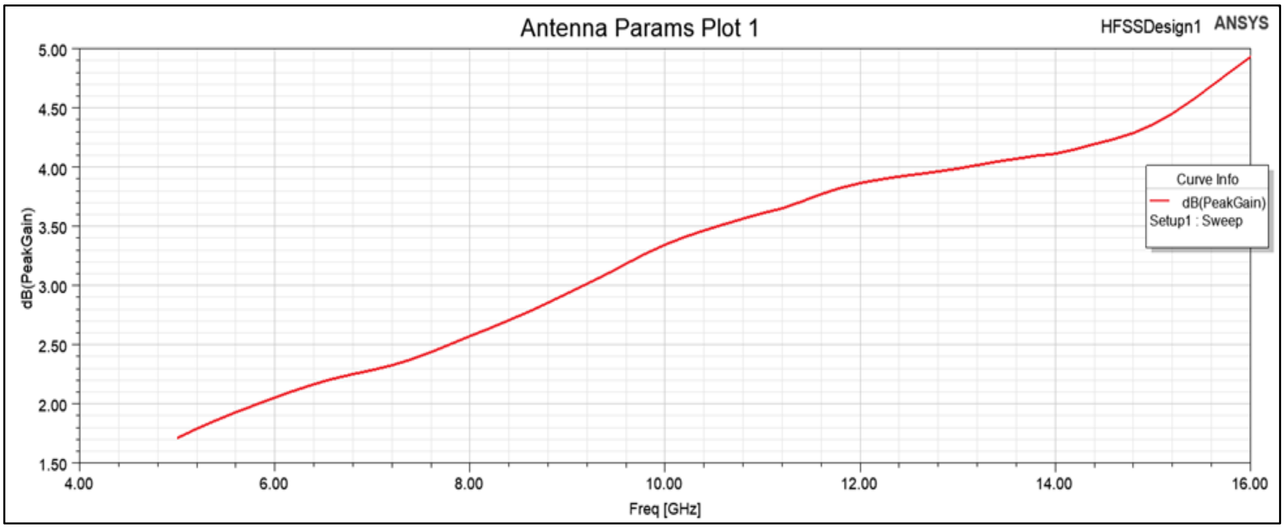

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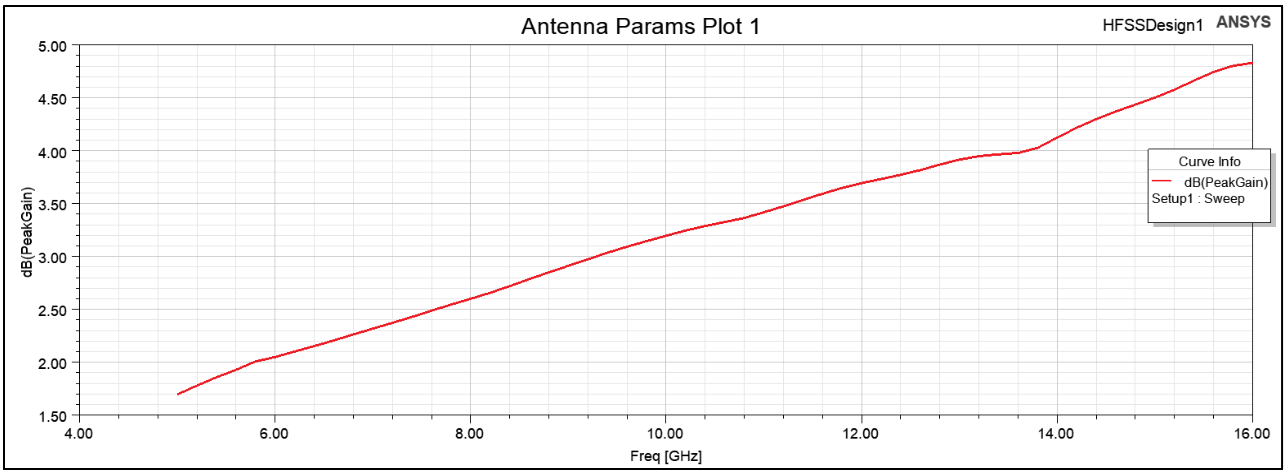
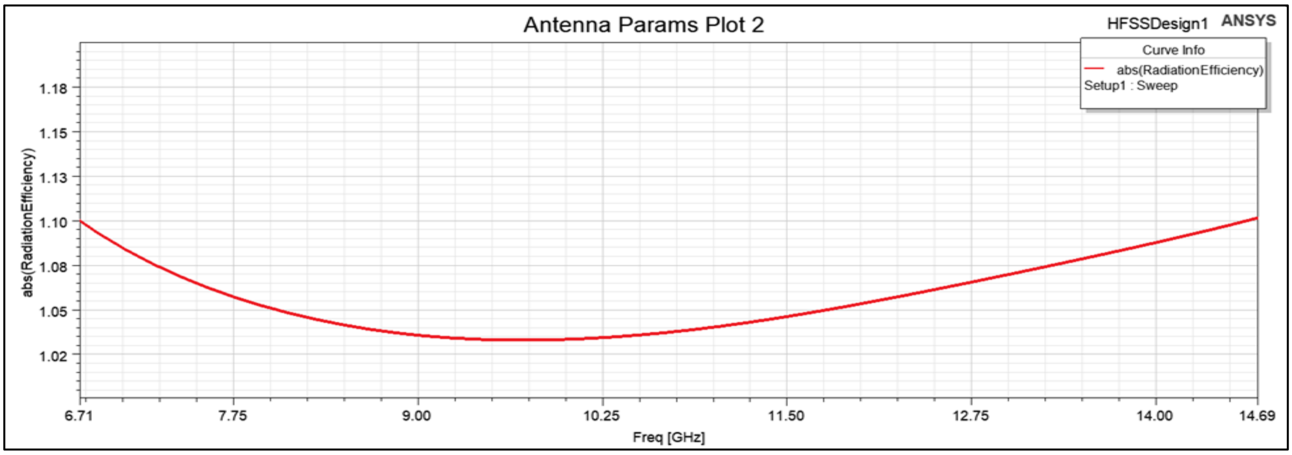


(d)

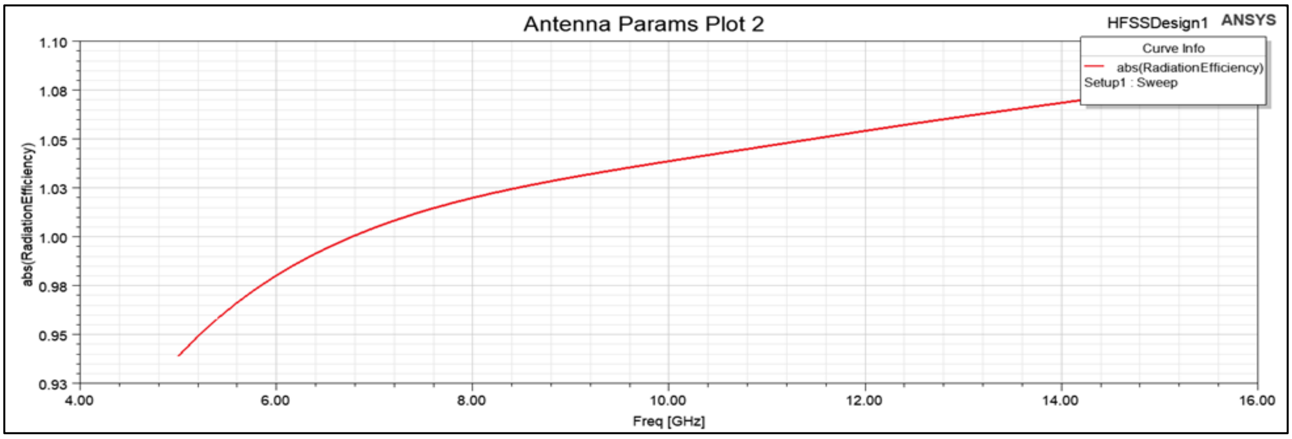
Fig. 5 Peak Gain of
(a) Two-dimensional microstrip patch antenna, (b) Conformal MPA with R1=15mm, (c) Conformal MPA with R2=30mm, (d) Conformal MPA with R3=45mm

Fig. 5 shows the Peak Gain for planar and nonplanar antennas. It is observed that the Peak gain increases slightly with increase in cylindrical radius, however, the increase is negligible [10]. It is further observed that the realized gain for two-dimensional MPA is 2.84dB. It can be seen that, due to bending effect, the realised gain of the conformal antennas increases. The realized gain of 3.26dB is observed for radius of 15mm.

VII. EFFECT OF CURVATURE ON ANTENNA EFFICIENCY



(a)



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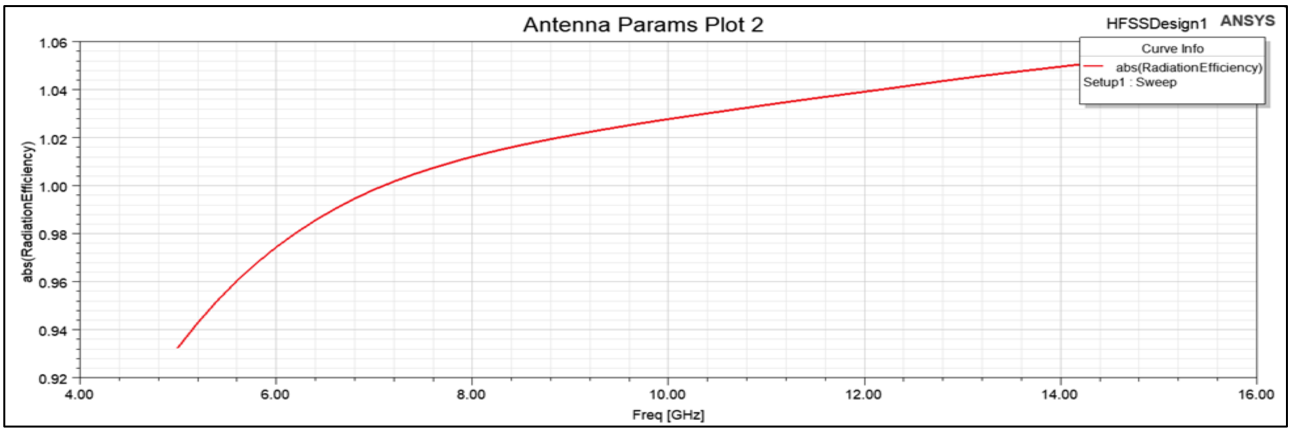

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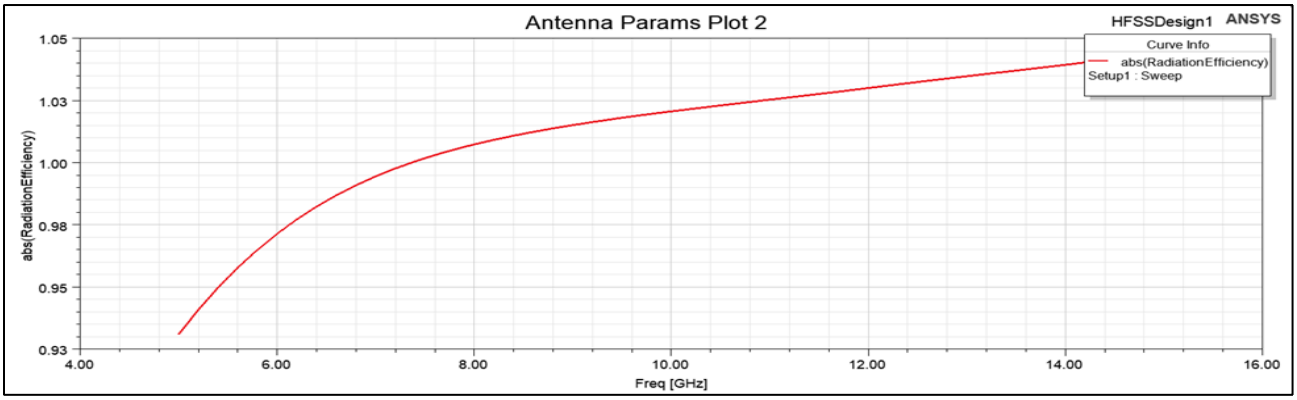

(d)

Fig. 6 Antenna Efficiency of
(a) Two-dimensional microstrip patch antenna, (b) Conformal MPA with R1=15mm, (c) Conformal MPA with R2=30mm, (d) Conformal MPA with R3=45mm

Fig. 6 depicts the antenna efficiency for planar and nonplanar antennas. It is observed from the results that the Antenna Efficiency reduces with the increase in cylindrical radius.

VIII. DESIGN COMPARISON

Table 1 Summary Results of the Antenna

Ser	Design	F_0 (GHz)	F_l (GHz)	F_h (GHz)	BW=F_h-F_l (GHz)	S11 at F_0
1	Planar Antenna	9.03	7.93	12.20	4.27	-25.92dB
2	R1=15mm	9.2	8.01	12.65	4.64	-26.75dB
3	R2=30mm	9.2	8.04	11.97	3.93	-25.09dB
4	R3=45mm	9.2	8.05	12.02	3.97	-25.98dB

Where,

F_0 = Resonant Frequency
F_l = Lower Frequency
F_h = Higher Frequency
BW = Bandwidth

Table 2 Summary Result

Ser	Design	F_0 (GHz)	Gain (dB)	BW (GHz)	S11 at F_0
1	Planar MP Antenna	9.03	2.80	4.27	-25.92dB
2	R1=15mm	9.2	3.12	4.64	-26.75dB
3	R2=30mm	9.2	3.14	3.93	-25.09dB
4	R3=45mm	9.2	3.14	3.97	-25.98dB

VIII. **CONCLUSION**

The design and analysis of bending effect on thin conformal microstrip patch antenna for X-band application is presented in this paper. The antenna is compared for Reflection coefficient (S11), Peak Gain and Radiation Pattern in E-Field (φ=90°) and H-Field (φ=0°). Antenna Peak Gain depends on the antenna efficiency (η) and directivity (D) parameters. The shift in frequency due to different nonplanar surfaces has been observed. The resonance frequency is affected by very small quantity which can be neglected and we can consider that the resonance frequency is constant with change in radius of curvature. It can be observed that this infinitesimal shift in resonant frequency is due to the E-field H-field distribution for different conformal MPA radius of curvature and remains constant with the introduction of non-planar surfaces. From the field distribution it is further observed that antenna is an omni-directional. Analysis results show that the bandwidth of the proposed planar and non-planar antenna is approximately same with minor reduction with increase in cylindrical radius. It is also observed that the Peak gain increases slightly with increase in cylindrical radius, however, the increase is negligible. It is further observed from the results that the Antenna Efficiency reduces with the increase in radius.

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