Design and Implementation of Triple Band Microstrip Patch Antenna using LTCC and RT Duroid Including Random Effect

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ABSTRACT

For most of the weather antenna application, the antenna must be covered with radome to enhance operational efficiency in all weather circumstances. This radome provides environmental protection and along with that it enhances antenna performance. The antenna manufacturer must evaluate radome scattering level so that they can estimate the parameter of cost effective antenna and can provide maximum efficiency at minimum power requirement. It is well known that continuous antenna measurement on the radome enclosed antenna is difficult to perform, the analysis of the radome's effect on antenna pattern can be done by practical method. We analyzed microstip patch antenna in IE3D by finite moment method. The proposed antenna design have been analyzed between 1GHz to 20GHz. When the proposed antenna design for different geometries (i.e. Rectangular and Circular) were examined for two dielectric i.e. RT Duroid 5870 with dielectric constant 2.33, loss tangent 0.0005 and Ferro A6M LTCC with dielectric constant 5.9, loss tangent 0.0012 the results are: In case of rectangular geometry directivity is 11.1329 and efficiency is 39.9296% and in case of circular geometry directivity is 7.67422 and efficiency is 100%.

General Terms

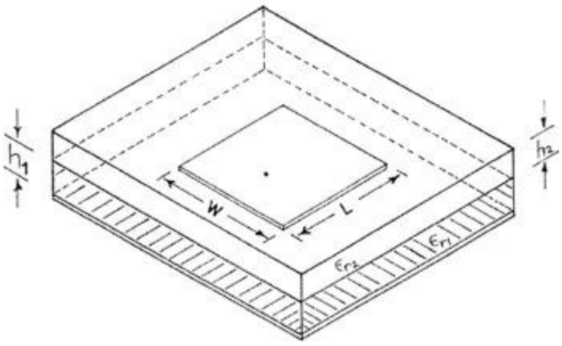
Rectangular microstrip patch antenna, circular microstrip patch antenna, radome effect.

Keywords

Microstrip antenna, IE3D simulator, losses, directivity and efficiency.

1. INTRODUCTION

Different geometries of patch antenna have been investigated by the researcher. In those studies they have not employed any dielectric substract in the form of radome above the patch. A significant change is observed in the characterstics of antenna when dielectric substract is used as radome. This radome protect the patch from environmental losses and enhance the antenna performance in terms of return losse, directivity and efficiency. In this paper we have analyzed all the three geometries and tried to find out at which feed point better directivity and efficiency can be obtained. For our detected feed points we have checked out all the remaining parameters such as dB and phase of S parameter, VSWR, Smith chart, radiation pattern, band width, total radiated power and average radiated power.



Microstrip patch antenna with dielectric substract as radome

2. EFFECTIVE PARAMETER

The principal purpose of antenna is to shield the antenna and associated equipment from environment. This improve the availability since the antenna is not effected by wind, rain or ice. A dielectric or ferrite coating on the surface of antenna can alter the electromagnetic characteristic, provide electrical insulation and protect the antenna from environment. Some ferrite and dielectric ceramic coating can allow certain antenna design to reduce in size or height while providing acceptable radiation characteristic. The effective parameters which define the required three geometries (i.e. Rectangle, Triangle and Circular) are effective length and breadth of rectangular patch, effective side of triangular patch and effective radius of circular patch.

(a) For Rectangular geometry

Equivalent dielectric constant of two dielectric substract is given by:

$$\epsilon_{eq} = \frac{\epsilon_{r1}\epsilon_{r2}(h_1 + h_2)}{\epsilon_{r1}\epsilon_{r2}h_1 + (h_1 + h_2)}$$

Width of rectangular patch is given by:

$$W = \frac{C}{2f_0\sqrt{\frac{\epsilon_r+1}{2}}}$$

Effective dielectric constant is given by:

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

Change in length is given by:

$$\triangle L = \frac{0.412h\left(\epsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\epsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)}$$

Effective length is given by:

$$L_{eff} = \frac{c}{2f_0\sqrt{\epsilon_{reff}}}$$

Actual length is given by:

$$L = L_{eff} - 2\triangle L$$

Taking f_o = 5GHz, lower dielectric as RT Duroid 5870 and upper dielectric as Ferro A6M, LTCC the above parameters comes out to be

ε_{eq} = 4.7467, W = 17.6981 mm, $\varepsilon_{r\ eff}$ = 5.046, ΔL = 0.230 mm, L_{eff} = 13.36 mm, L = 12.9 mm.

(b) For Triangular Geometry

The quantity ε_{eq} (equivalent dielectric constant) is same as that of above case i.e. it of multilayered rectangular patch antenna with width W and length L. This model can be further extended to compute the ε_{eq} of triangular patch using an equivalence relation between a rectangular patch of width W and length L and an equilateral triangular patch with side length a operating at same frequency. To account for equal static fringing fields, equal area has been considered as the basis of equivalence, resulting in

$$WL = \left(\frac{\sqrt{3}}{4}\right)a^2$$

Where W = width of rectangular patch

L = length of rectangular patch

a = side of equilateral triangle.

Taking f_o = 5GHz, lower dielectric as RT Duroid 5870 and upper dielectric as Ferro A6M, LTCC the above parameters comes out to be

a = 22.9619 mm, h = 19.886 mm.

(c)For Circular Geometry

Resonant frequency is given by:

$$f_0 = \frac{K_{nm}c}{2\pi a\sqrt{\epsilon_{eq}}}$$

where $K_{nm} = 1.8412$

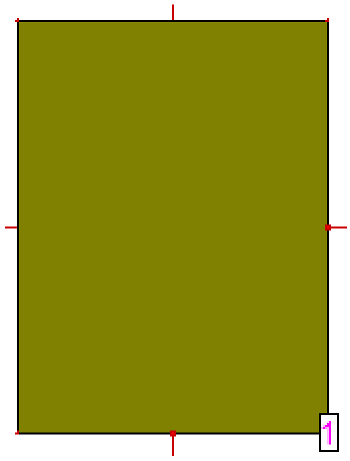
Effective radius is given by:

$$a_e = a\left\{1 + \frac{2h}{\pi\epsilon_r a}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{\frac{1}{2}}$$

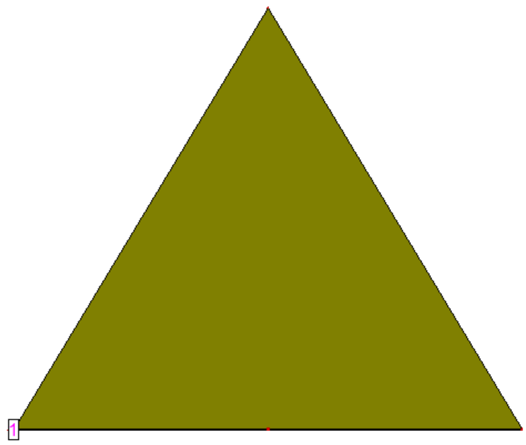
Taking f_o = 5GHz, lower dielectric as RT Duroid 5870 and upper dielectric as Ferro A6M, LTCC the above parameters comes out to be a = 8.073 mm, a_e = 8.241 mm.

3. PROPOSED ANTENNA DESIGN

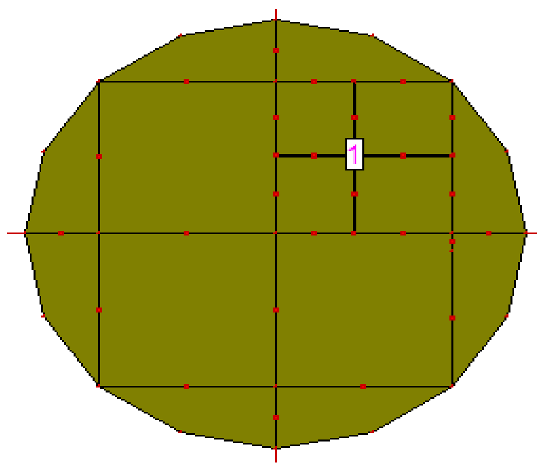
(a) For Rectangular Geometry



(b) For Triangular Geometry



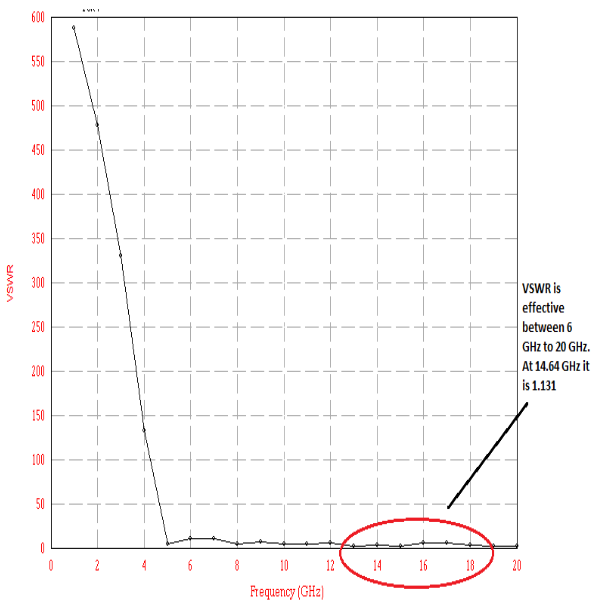
(c) For Circular Geometry



Simulated Microstrip Patch Antenna In Ie3d Simulator For Rt Duroid 5870 And Ferro A6m, Ltcc Considering Radome Effect

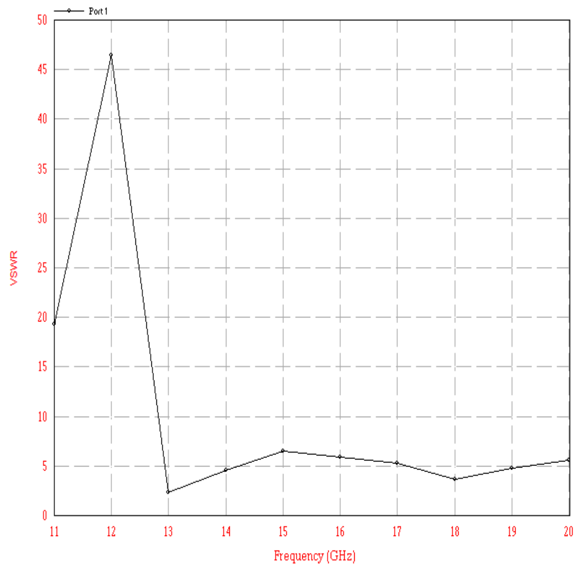
(1) VSWR VS FREQUENCY

For Rectangular Geometry



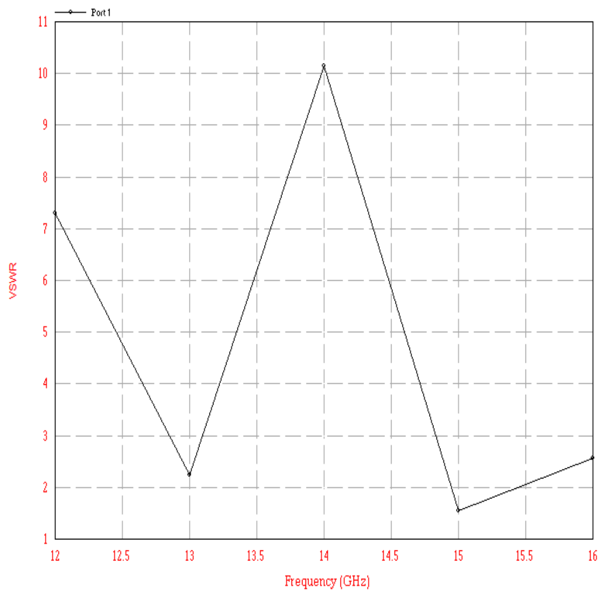
For the proposed design the value of VSWR is effective at 14.64 GHz and it is found to be 1.131 at (6.45,-8.75).

For Circular Geometry



For the propose is geometry the value of VSWR is effective is at 15 GHz and it is found to be 1.806 at (2.975,-2.525).

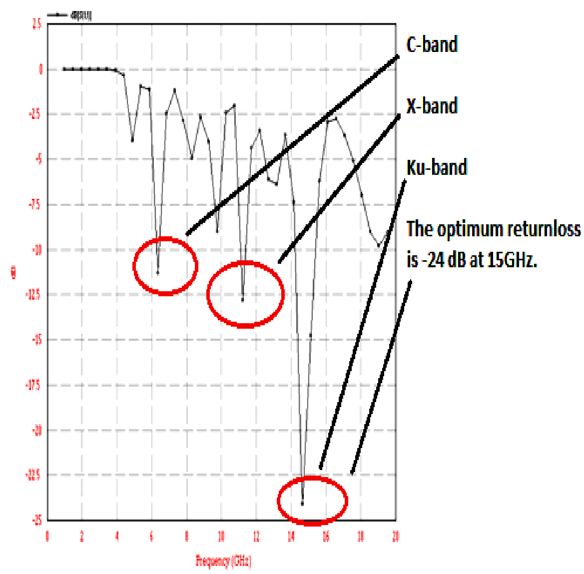
For Triangular Geometry



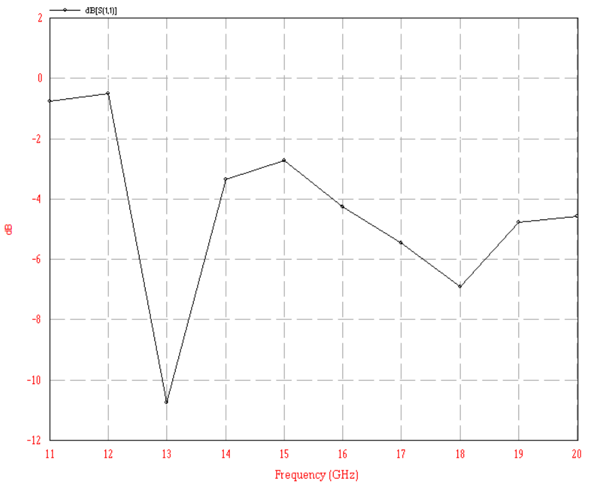
For the proposed geometry the value of VSWR is effective at 15 GHz and it is found to be 1.544 at (11.575,18.3).

(2) RETURNLOSS VS FREQUENCY

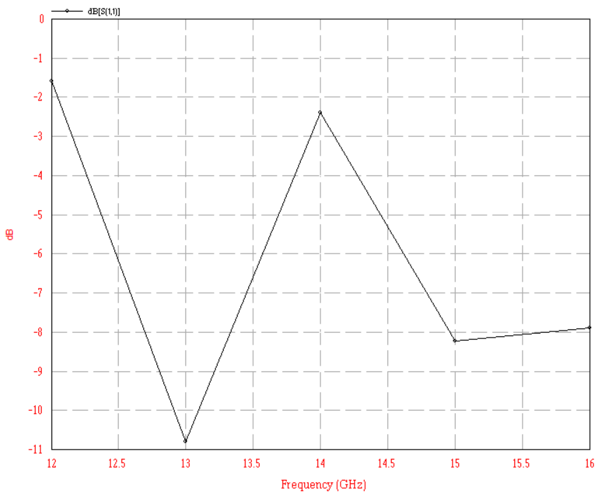
For Rectangular Geometry



For Circular Geometry

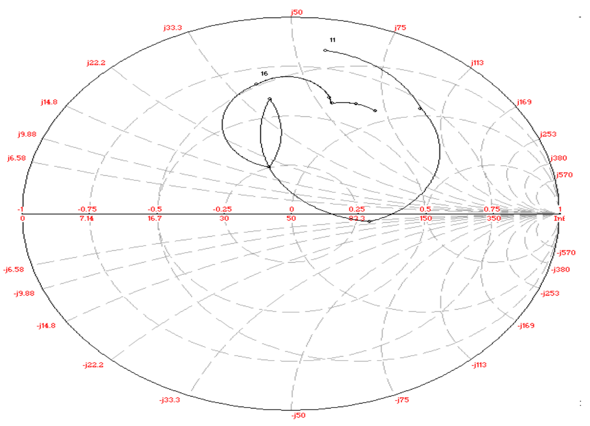


For Triangular Geometry

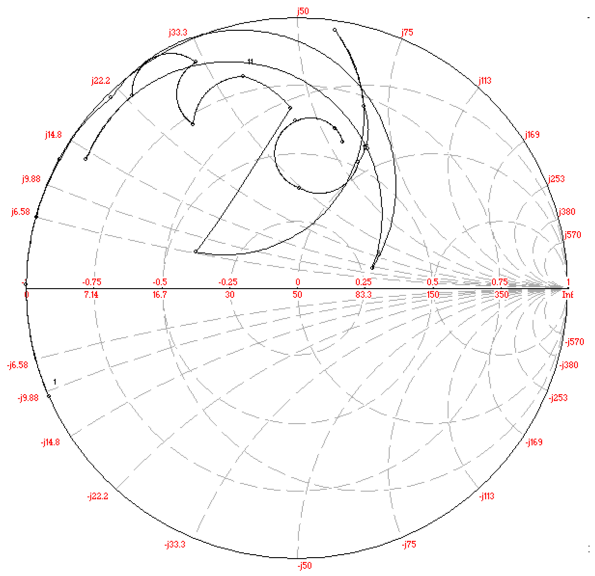


(3) SMITH CHART FOR DIFFERENT GEOMETRIES

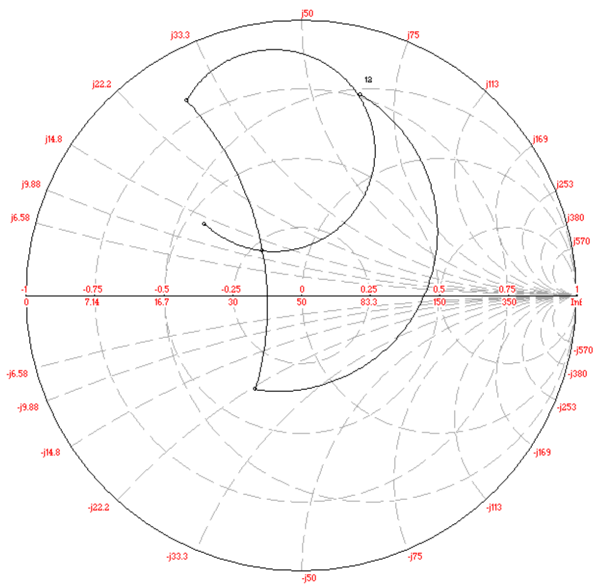
For Rectangular Geometry



For Circular Geometry

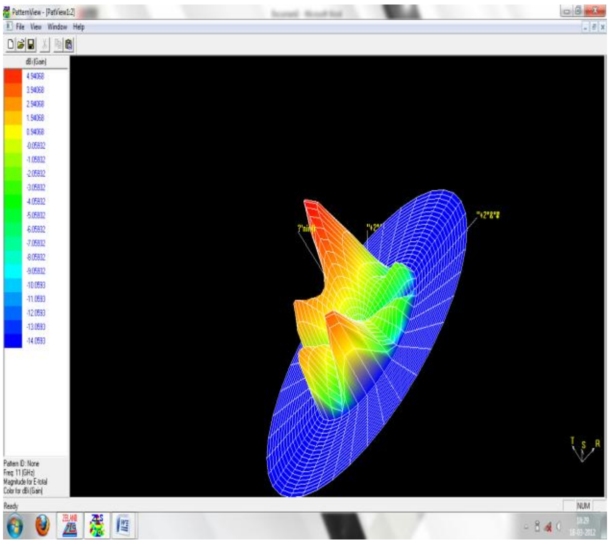


For Triangular Geometry



(4) RADIATION PATTERN

For Rectangular Geometry



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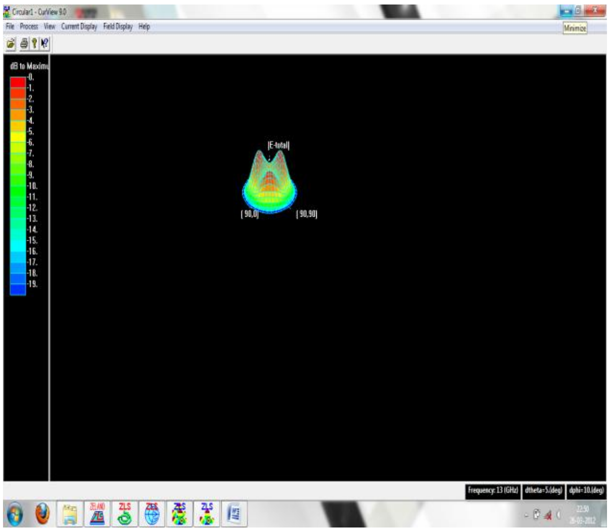
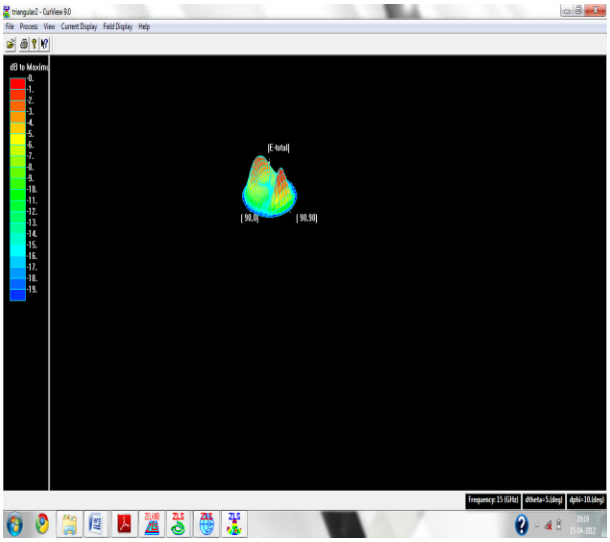
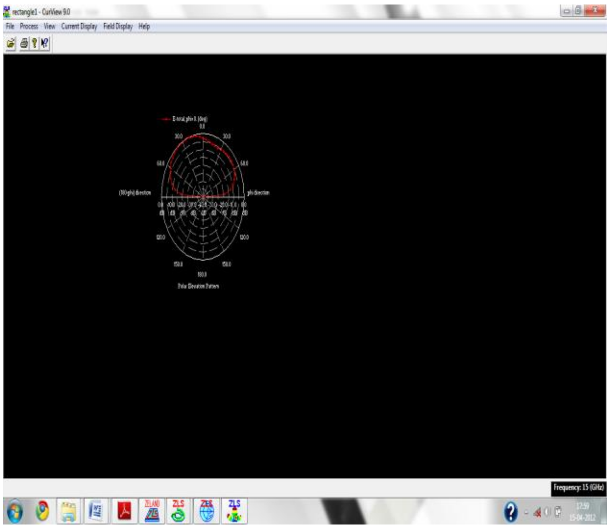


For Triangular Geometry



(5) 2D POLAR PLOT

For Rectangular Geometry



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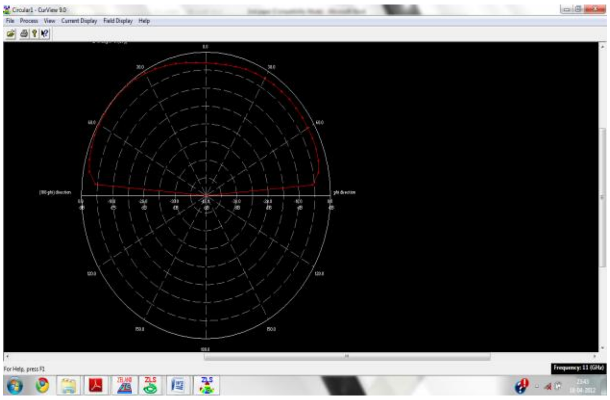
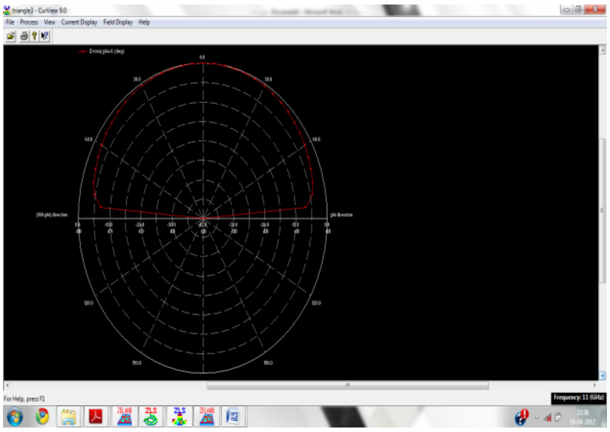


For Triangular Geometry



(6) SIMULATION TABLE

(a) For Rectangular Geometry

Co-ordinates	Return loss	Frequency	Bandwidth	Directivity	Efficiency(%)	Total radiated power	Average radiated power
(0,0)	-15.5 dB	15 GHz	6 %	7.19072	15.6955	0.0015271f	0.000121412
(-6.45,8.84905)	-15.8 dB	15 GHz	6 %	7.19072	25.1378	0.0015271	0.000121412
(0,8.84905)	-12 dB	15 GHz	7.33 %	9.71027	25.1378	0.0015185	0.000120838
(6.45,8.84905)	-15.8 dB	15 GHz	6.66 %	9.7088	25.1408	0.0024478	0.000194789
(-6.45,4.42452)	-9.2 dB	13 GHz	–	9.79427	33.8952	0.00299107	0.000238022
(-3.225,4.4245)	-12.8 dB	14 GHz	4.29 %	11.1329	39.9247	0.0037796	0.000300771
(3.225,4.42452)	-12.8 dB	14 GHz	3.57 %	11.1329	39.9266	0.00377948	0.000300771
(6.45,4.424525)	-9 dB	13 GHz	–	9.79398	33.9015	0.00029925	0.000238135
(-6.45,0)	-8.5 dB	15 GHz	–	7.89451	16.7494	0.00143156	0.00011392
(6.45,0)	-8 dB	15 GHz	–	7.89451	16.7494	0.0014315	0.00011392
(-6.45,-4.42425)	-9.2 dB	13 GHz	–	9.79394	33.9027	0.00299258	0.00011392
(-3.225,-4.42425)	-14.8 dB	14 GHz	2.85 %	11.13	38.0744	0.00028965	0.00028965
(3.225,-4.424525)	-12.8 dB	14 GHz	2.85 %	11.1329	39.9296	0.00377988	0.000300793
(6.45,-4.424525)	-9.3 dB	13 GHz	–	9.79437	33.8958	0.0029911	0.000238026
(-6.45,-8.84905)	-15.9 dB	15 GHz	6.66 %	9.71014	25.1474	0.00244858	0.000194852
(0,-8.84905)	-12 dB	15 GHz	4 %	8.57795	16.1951	0.00151896	0.000120875
(6.45,-8.75)	**-24 dB**	15 GHz	**7.3 %**	9.7115	25.1466	0.00244879	0.000194868

(b) For Circular Geometry

Co-ordinates	Return loss	Frequency	Directivity	Efficiency	Total Radiated power	Average Radiated Power
(0,0)	17.5 dB	14 GHz	5.33414	10.1661 %	0.000154945	1.23301e-005
(-8.241,0)	-9.3 dB	13 GHz	7.2455	44.9799 %	0.00396685	0.000315672
(5.85,5.85)	-9.3 dB	13 GHz	7.26441	44.7672 %	0.00393232	0.000312924
(2.925,5.775)	-8.1 dB	13 GHz	6.98546	**100 %**	0.00187444	0.000321076
(2.6,3.025)	-8 dB	13 GHz	6.59739	**100 %**	0.007911516	0.00101703
(-1.35,6.95)	-10.8 dB	13 GHz	7.67422	47.8258 %	0.00438037	0.000348579
(4.8,-1.1)	-4.6 dB	16 GHz	7.57151	**100 %**	0.00233025	0.000502774
(4.8,1.1)	-4.6 dB	16 GHz	5.96283	84.5167 %	0.00242399	0.000192895
(-4.8,1.1)	-7 dB	6 GHz	4.79921	1.60968	5.96214e-008	4.74452e-008
(-4.8,-1.1)	7 dB	6 GHz	4.79921	1.60972 %	5.9213e-007	4.74452e-008
(2.975,-2.525)	-10.9 dB	6 GHz	4.8182	1.60305 %	5.84347e-007	4.65009e-008

(c) For Triangular Geometry

Co-ordinates	Returnloss	Frequency	B.W.	VSWR	Directivity	Efficiency	Total radiated power	Average radiate power
(0,0)	-10.8 dB	13 GHz	1.53 %	1.809	9.71984	90.346%	0.00279623	0.0002225
(22.95,0)	-10.6 dB	13 GHz	1.53 %	1.836	7.60208	**100%**	0.00369583	0.0002225
(11.45,7.825)	-8.6 dB	14 GHz		2.178	7.1379	**100%**	6.2525e-005	5.76507e-005
(11.575,18.3)	-13.5	15 GHz	5.66 %	1.544	8.82556	19.6309 %	0.00187321	0.000149056

7.CONCLUSION

All the three geometries of patch antenna have investigated including the radome effect. Results are found to be best in case rectangular patch antenna in term of bandwidth. However the feed points which produce the remarkable results lie on the edge of rectangular patch but results are not remarkable in case of directivity and efficiency. Maximum directivity and efficiency which is obtained in this case is 11.1329 and 39.9247. Maximum value of total radiated power and average radiated power is 0.00377988 Watt and 0.000300793 Watt. The optimum value of VSWR is 1.386 . In case of circular geometry the maximum directivity is 7.57151 and efficiency is 100%. Maximum value of total radiated power and average radiated power is 0.00791516 and 0.000502774. The optimum value of VSWR is 1.806. In case of triangular geometry bandwidth is achieved up to 5.66%. Maximum directivity which can be achieved is 9.71984 and efficiency is 100%.Maximum value of total radiated power and average radiated power is 0.00369583 and 0.00035221. The optimum value of VSWR is 1.544.

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