Design and Analysis of Circular Patch & Patch-Slot Antenna with Dimensional Characterization

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ABSTRACT
This paper describes the design and analysis of circular patch and patch-slot antenna with respect to dimensional characterization. Patch and substrate will play the vital role in the performance of the microstrip patch antenna. Dimensions and material of the substrate has an influence on the output parameters of the antenna. The substrate thickness variation effects with respect to dimensional characterization are analyzed for circular patch as well as circular slot patch antenna. A comparative analysis is done for the two models and Simulational output parameters return loss, VSWR, gain, radiation patterns and field distributions for both the cases are presented in this work.

KEYWORDS: *Circular patch, Circular patch-slot, Dimensional characterization*

I. INTRODUCTION

The traditional antennas are commonly replaced by the latest microstrip or patch antennas which have low weight, less size, less production cost. A Microstrip antenna comprises a dielectric substrate separating radiating patch from the ground plane. Metals like copper, gold are used as the patch which can take any shape. Patch antennas are economical, ease of manufacture and serve better gain when compared to the typical monopole and dipole antennas which were conventionally employed in the mobile phones. They are also used in space applications due to their light weight and small size. They have an ability to withstand severe environments due to their simplicity in structure [1-4]. Ansoft HFSS is used to design and simulate the models.

II. SUBSTRATE MATERIAL

The substrate material plays a significant role in the design and simulation of microstrip patch antenna. The material selection depends upon permittivity, conductivity, thermal expansion and cost. In this work, RT-Duroid is selected as the substrate material with dielectric constant of 2.2 and dielectric loss tangent of 0.009 [5-8].

III. DESIGN SPECIFICATIONS

The design considerations for the proposed circular patch antenna (Fig.1) on RT-Duroid substrate material with a relative dielectric constant of 2.2 with thickness varied from 1mm to 2mm in the steps of 0.2mm.The diameter of the circular patch is 3.1cm. The radius of the feed element=0.023cm.

The specification for the circular patch-slot antenna (Fig.2) on RT-Duroid substrate material with a relative dielectric constant of 2.2 with thickness varied from 1mm to 2mm in the steps of 0.2mm.The diameter of the circular patch is 3.1cm.Length of the slot= 0.25 cm, Width of the slot= 0.05 cm, Frequency of operation= ,Radius of the feed element=0.025 cm.

Coaxial feeding is used in the design of these antennas because of impedance matching and easy construction.

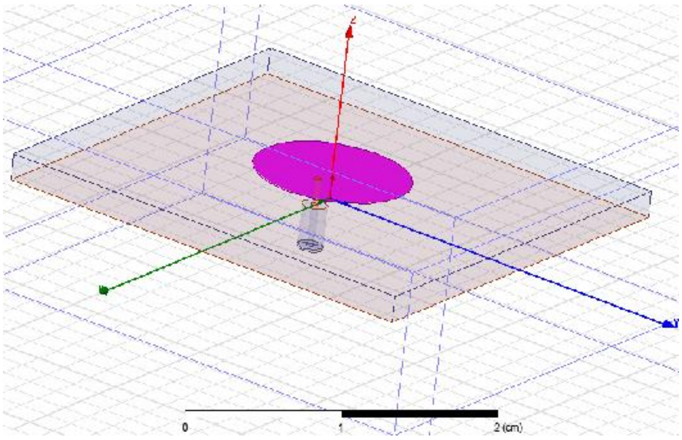

Fig.1 Circular Patch Antenna

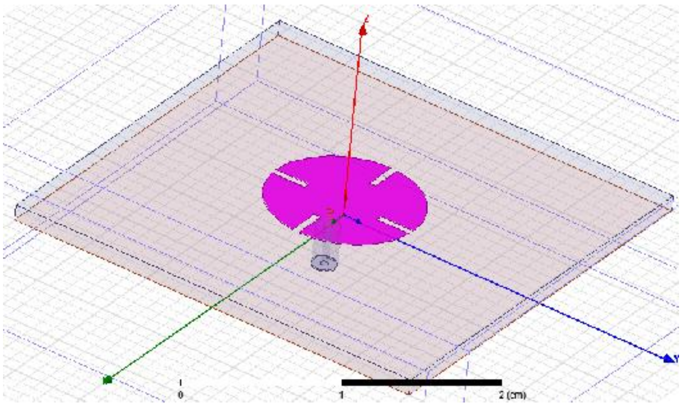

Fig.2 Circular Patch Antenna with Slots

IV. RESULTS AND DISCUSSION

The Table 1 shows Return Loss, VSWR and 2-D Gain for the designed circular patch antenna with substrate thickness from 1mm to 2mm in the steps of 0.2mm.A comparative analysis is made for the obtained results.

Table 1 Circular Patch Antenna Output Parameters

S.No	Parameter	Substrate Thickness							
		1mm		1.2mm		1.4mm	1.6mm	1.8mm	2mm
1	**Return Loss (dB)**	-24.6 at 10.4 GHz	-16.6 at 22.1 GHz	-20.1 at 10.2 GHz	-12.0 at 21.9 GHz	-18.5 at 10.2 GHz	-15.3 at 10.0 GHz	-11.9 at 9.84 GHz	-10.4 at 9.8 GHz
2	**VSWR**	1.12	1.34	1.21	1.66	1.26	1.41	1.67	1.86
3	**Gain (dB)**	8.10		8.16		8.19	8.20	8.16	8.12

The table 2 shows Return Loss, VSWR and 2-D Gain for the designed circular patch-slot antenna with substrate thickness from 1mm to 2mm in the steps of 0.2mm.A comparative analysis is made for the obtained results.

Table 2 Circular Patch-Slot Antenna Output Parameters

S.No	Parameter	Substrate Thickness							
		1mm		1.2mm		1.4mm	1.6mm	1.8mm	2mm
1	**Return Loss (dB)**	-19.4 at 22.0 GHz	-10.9 at 9.5 GHz	-14.1 at 9.5 GHz	-12.8 at 21.8 GHz	-18.7 at 9.4 GHz	-22.0 at 9.4 GHz	-26.2 at 9.3 GHz	-19.5 at 9.2 GHz
2	**VSWR**	1.23	1.78	1.48	1.59	1.26	1.16	1.10	1.23
3	**Gain (dB)**	8.04		7.99		7.94	7.83	7.75	7.70

Table 3 Additional Antenna Parameters of Circular Patch Antenna

S.No	Quantity	Substrate Thickness					
		1mm	1.2mm	1.4mm	1.6mm	1.8mm	2mm
1	**Max U** (W/sr)	0.001522	0.002527	0.003539	0.003726	0.003183	0.002507
2	**Peak Directivity**	6.5336	6.6088	6.6266	6.6278	6.5694	6.5291
3	**Peak Gain**	6.4645	6.5533	6.604	6.6092	6.5597	6.5013
4	**Peak Realized Gain**	4.4505	5.5223	6.1977	6.3878	6.1863	5.7311
5	**Radiated Power** (W)	0.002927	0.004806	0.006712	0.007065	0.006090	0.004825
6	**Accepted Power** (W)	0.002959	0.004847	0.006735	0.007085	0.006099	0.004846
7	**Incident Power** (W)	0.004298	0.00575s2	0.007177	0.007331	0.006467	0.005497
8	**Radiation Efficiency**	0.98942	0.9916	0.99658	0.99718	0.99852	0.99575
9	**Front to Back Ratio**	88.045	92.178	119.17	173.65	285.15	396.01

Table 4 Additional Antenna Parameters of Circular Patch-Slot Antenna

S.No	Quantity	Substrate Thickness					
		1mm	1.2mm	1.4mm	1.6mm	1.8mm	2mm
1	**Max U** (W/sr)	0.002405	0.001988	0.001552	0.001356	0.001134	0.000994
2	**Peak Directivity**	6.4804	6.3655	6.2767	6.1133	5.9987	5.9165
3	**Peak Gain**	6.3823	6.3007	6.2363	6.0771	5.9663	5.8932
4	**Peak Realized Gain**	3.568	3.7974	3.7945	3.7994	3.6075	3.4053
5	**Radiated Power** (W)	0.004664	0.003925	0.003108	0.002788	0.002377	0.002111
6	**Accepted Power** (W)	0.004736	0.003965	0.003129	0.002805	0.002390	0.002119
7	**Incident Power** (W)	0.008472	0.006579	0.005142	0.004486	0.003952	0.003668

8	**Radiation Efficiency**	0.98487	0.98981	0.99357	0.99408	0.9946	0.99606
9	**Front to Back Ratio**	97.716	126.79	159.58	180.64	359.16	407.94

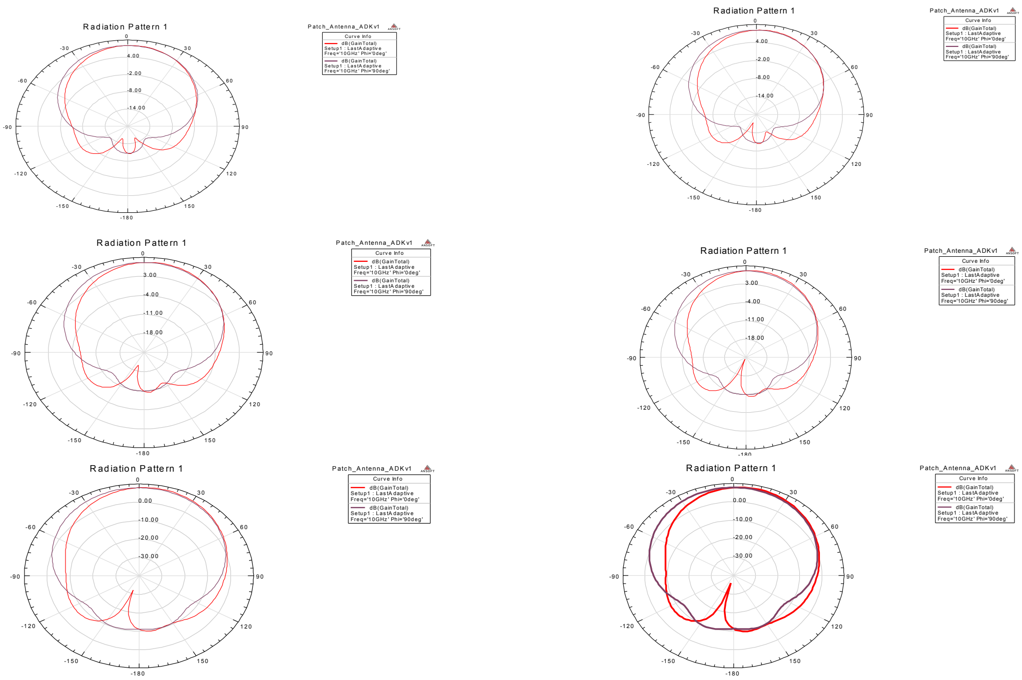

Fig.3 Radiation Pattern of Circular Patch Antenna

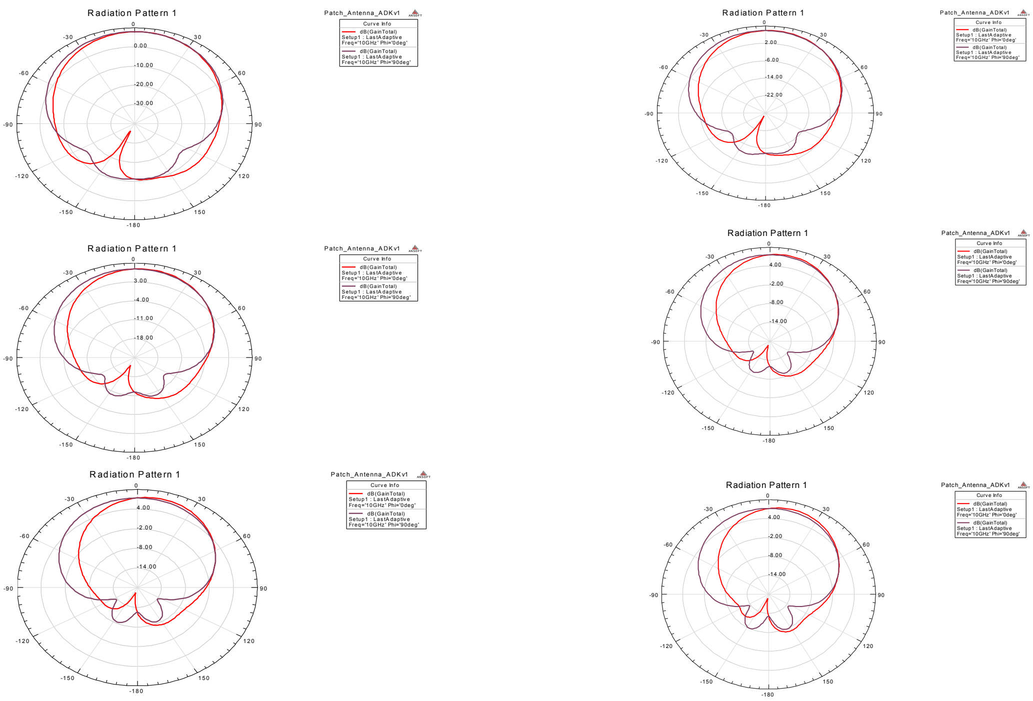

Fig.4 Radiation Patterns of Circular Patch-Slot Antenna

Table 3 and 4 shows the antenna additional parameters with respect to the change in the thickness of the substrate. The far-zone electric field lies in the E-plane and far-zone magnetic field lies in the H-plane. The patterns in these planes are referred to as the E and H plane patterns respectively. Figure 3 and 4 shows the antenna cross and co-polarization radiation pattern curves for both circular patch and circular patch-slot. Figure 5 and 6 shows the antenna E-field distribution for circular patch and circular slot patch. Figure 7 and 8 shows the antenna H-field distribution for circular patch and circular slot patch.

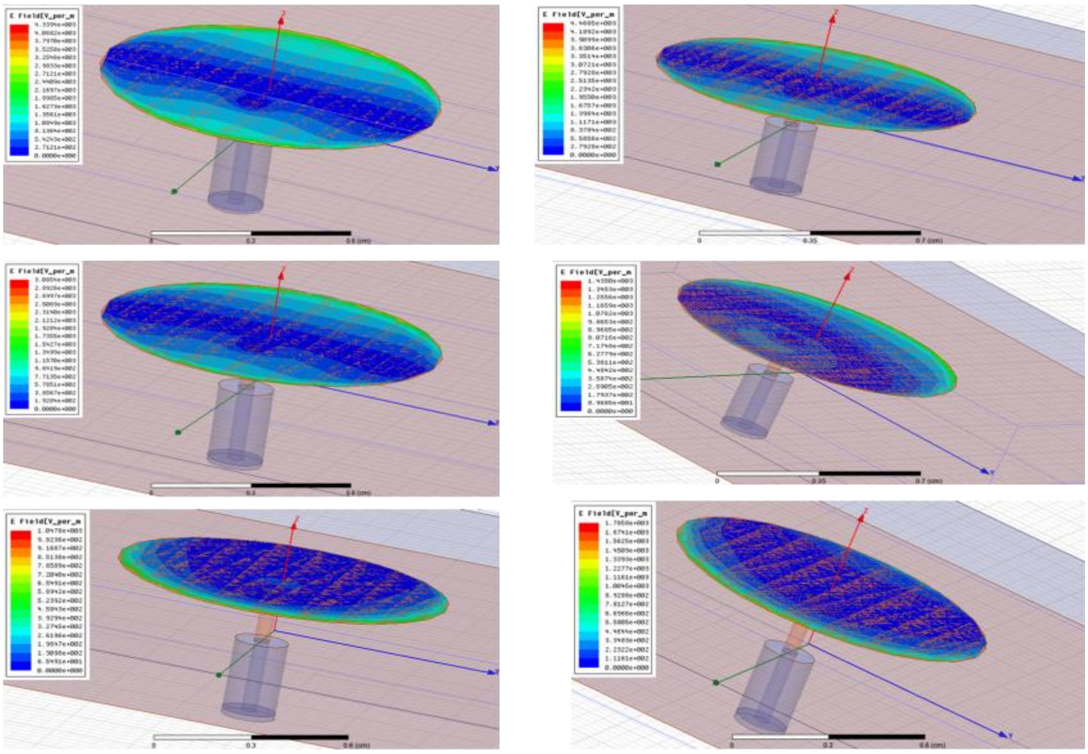

Fig.5 E-Field Distribution of Circular Patch Antenna

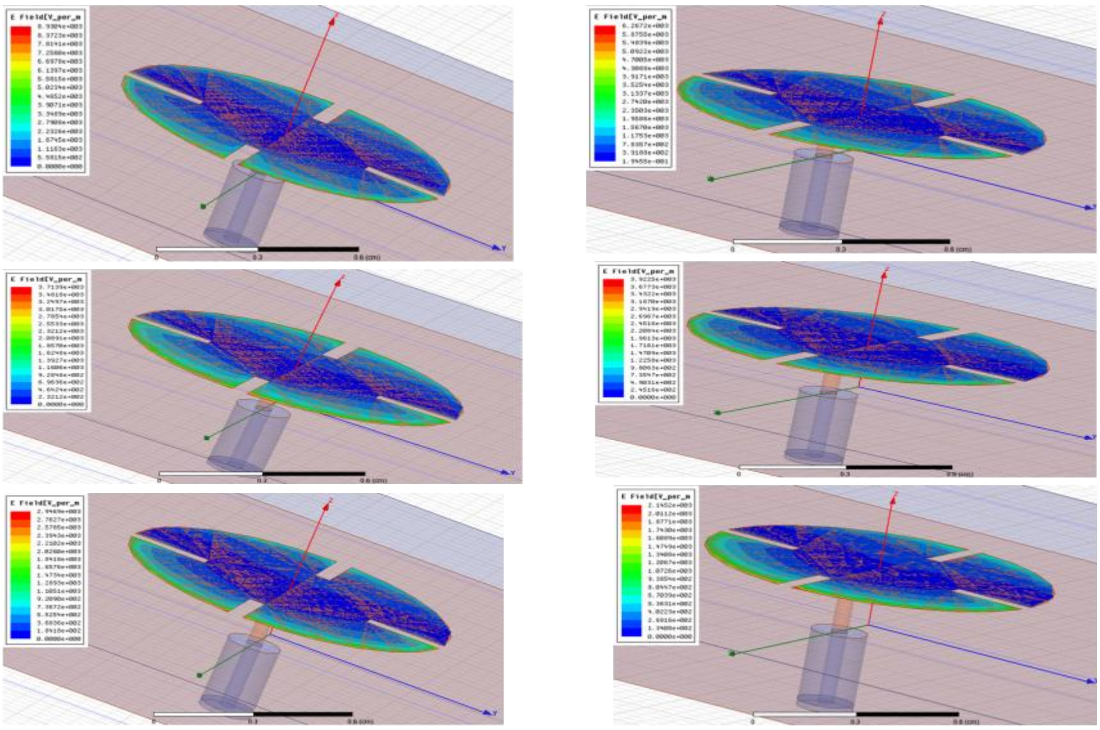

Fig.6 E-Field Distribution of Circular Patch-Slot Antenna

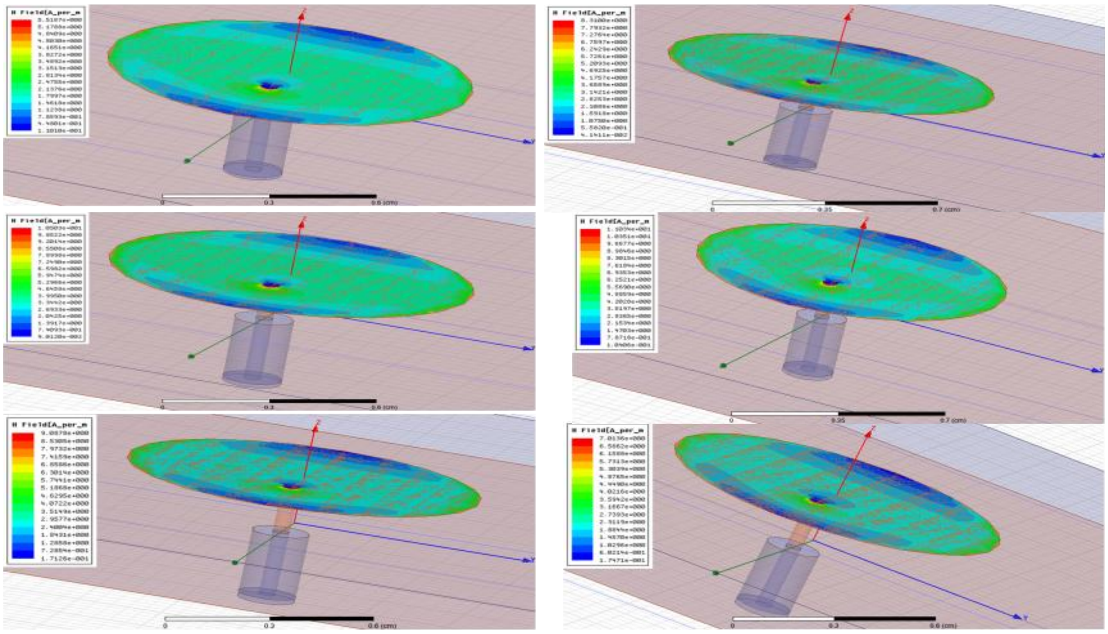

Fig.7 H-Field Distribution of Circular Patch Antenna

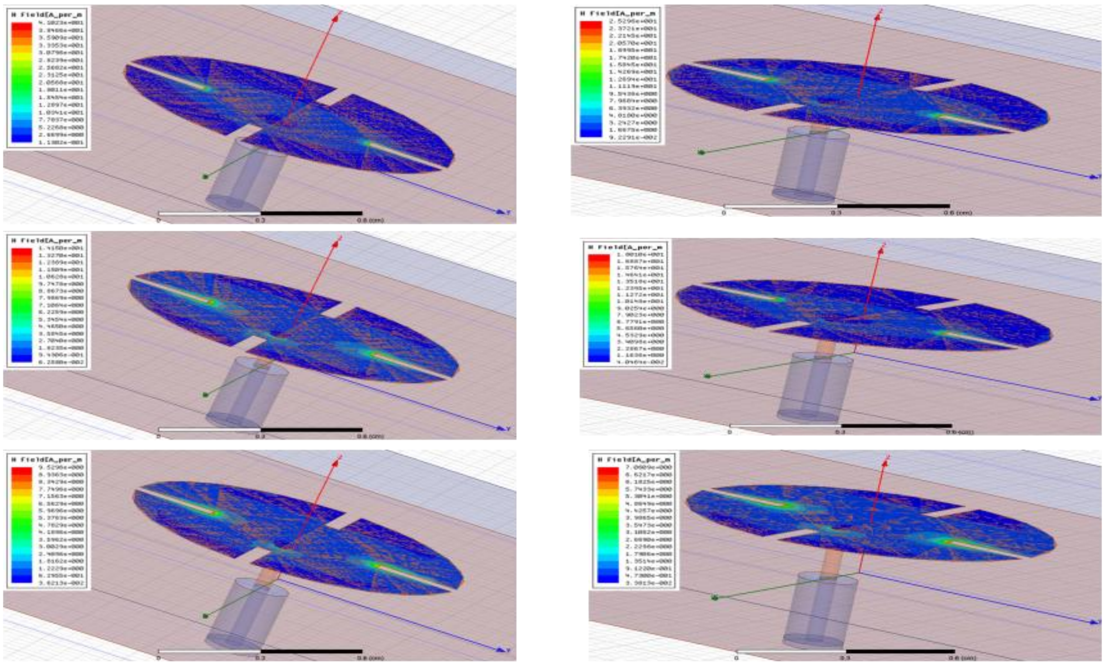

Fig. 8 H-Field Distribution of Circular Patch-Slot Antenna

V. CONCLUSION

Comparative analysis of circular patch and circular slot patch antenna was done by changing the substrate thickness. It is observed that the antenna was resonating at dual frequency and with change in substrate thickness, at each time the resonant frequencies and the antenna parameters are changed. The gain is increased first and then decreased when thickness increases from 1mm to 2mm for the circular patch antenna, but for the case of circular slot antenna the gain decreased with increase in the substrate thickness. The same behavior is observed for the case of radiation efficiency, peak gain and peak directivity. Overall we observed that the stability in the performance characteristics for circular slot is showing superior results compared to non symmetrical behavior of the circular patch antenna.

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