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Design of a CPW fed Complementing E shaped patch antenna.

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Abstract: The design of a planar complementing E shaped co-planar waveguide fed micro-strip patch antenna for multiband applications has been presented. It resonates at three centre frequencies of 5.4GHz, 6.7GHz and 9.5GHz with more than 100MHz bandwidth around each centre frequency which allows it to be suitable for C and X band applications, WLAN/HIPERLAN and defence applications. The introduction of slots and complementing design optimizes the result in terms of parameters like S- parameter, VSWR (Voltage Standing Wave Ratio), gain, bandwidth and radiation pattern which are viewed in HFSS simulation. The design fuses two previous designs of E shaped patch and complementing C shaped patch to obtain improved results.

Keywords: Co-planar Waveguide, Centre Frequency, VSWR, X Band, C Band

I. INTRODUCTION

Micro-strip antennas (MSA) are the most sought after option today when it comes to wireless, handheld, compact devices with minimum size requirements. The low profile antennas stand out in terms of miniaturized size availability, lesser fabrication cost, ease of fabrication and integration into the host system. Experimenting with micro-strip antennas brings out that the output properties like S_{11} parameter, gain, VSWR (Voltage Standing Wave Ratio), resonant frequency, bandwidth, radiation pattern and properties depend upon the design parameters like the length and the width of the patch, the height of the substrate, material properties of the dielectric used and different feeding techniques. Due to the bandwidth and gain limitations of MSA, it is important that the shape of the patch is chosen to obtain the optimum output [1].

Various methods to improve the gain and the bandwidth like introduction of slots of various shapes into the simple patch [2], increasing substrate height [3], stacked patches [4], reactive capacitive loading etc. [5] have already been developed. However, there are limitations of each technique like increasing the substrate thickness causes higher undesired radiation, increased inductive reactance of the longer coaxial probe etc. Here, the design with the introduction of two parallel slots into the simple rectangular patch and the complement of the slots on the same plane forming the metallic radiating patch structure has been presented. The design is planar with the ground plane on the same plane as the metallic patch. The planar patch antenna is fed by a coplanar waveguide (CPW) of 1mm width and 1mm length between the patch and ground plane. The planar structure compensates for the inductive reactance of the coaxial fed structure and the self-complementing structure improves the bandwidth [6-8]. The design is an improved amalgamation of E shaped patch proposed previously [9] and a CPW fed self-complementing C shaped planar patch antenna [10].

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II. PROPOSED ANTENNA DESIGN

Figure 1 gives the geometrical description of the metal patch which is composed of two parts: the E patch with two parallel similar slots and the two protruding parallel slots complementing the slots in the E patch. A rectangular patch of width 18mm and length 26mm with two equivalent parallel slots of width 17mm and length 6mm each forms the E shape. The slots made forming the complementary portion are also each of length 6mm and width 17.1mm. The 0.1mm increase in width of these slots is to overcome the model error in HFSS which arises as the FEM (Finite Element Method) fails to compute results at sharp zero dimension transitions between edges. This patch lies on the top of a substrate of width 80mm, length 80 mm and height 1.6mm. RT Duroid (5880) which has a relative permittivity ε_r of 2.2 is the dielectric material of the substrate.

The material of the conducting patch and ground plane is copper. Outside a rectangle of length 28mm and width 37 mm with its center coinciding with the center of the substrate, lies the ground plane extending till the edges of the substrate. Since this is planar structure, coplanar waveguide (CPW) is used to feed the patch antenna. The feed of 1mm x 1mm placed between the Complementing E and ground plane, with ground plane as the reference plane is used to excite the antenna structure.

The design dimensions of the patch therefore are:

Table1. Design Parameters

S.No.	Design Parameter	Value
1	Length of the E patch(L)	26mm
2	Width of the E patch(W)	18mm
3	Length of the slot(l)	6mm
4	Widthth of the slot (w)	17mm
5	Length of the complement to slot	6mm
6	Width of the complement to slot	17.1mm

7	Length of the substrate	80mm
8	Width of the substrate	80mm
9	Height of the substrate (h)	1.6mm
10	Relative permittivity of the dielectric (ε_r)	2.2

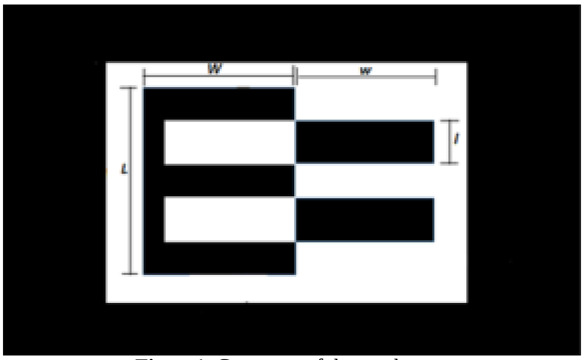

Figure1. Geometry of the patch.

This design is simulated in HFSS (High Frequency Structure Simulator) with the above outlined parameters and the output results are analyzed. Figure 2 shows the proposed design simulation in HFSS with the optimized design parameters for good performance.

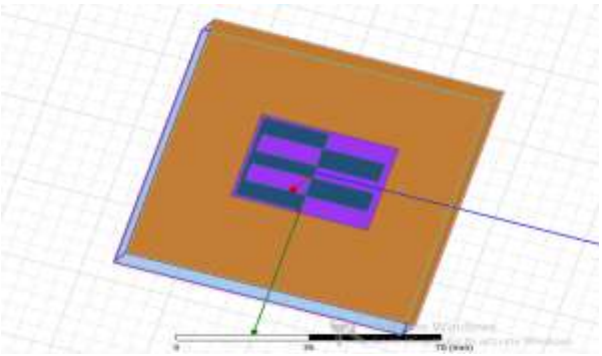

Figure2. Simulated design in HFSS.

The black portion indicates the metal patch, the brown portion showing the ground plane and the tiny red square being the CPW feed.The radiation box covers the entire patch and extends to 20mm above the patch in air. Several output parameters have been investigated using the HFSS tool.

III. Results and Discussion

The simulated results for the S_{11} parameter are shown in Fig. 3 where three peaks at centre frequency of 5.4GHz, 6.7GHz and 9.5GHz are obtained with S_{11} parameter going well below -15dB. The reflected power is what is indicated by this parameter and its value less than -10dB indicates reflected power being less than one tenth of the incident power proportionally.

The VSWR ratio obtained from the simulation is shown in Fig.4 with its value at all three centre frequencies being acceptable. A VSWR of 1 means that the reflection coefficient is zero. Thus, the VSWR obtained should be as close to the ideal value of 1 as possible. From Fig. 4, it is seen that the VSWR at centre frequency of 5.4GHz is 1.2585, at centre frequency of 6.7 GHz is 1.0717 and that at centre frequency of 9.5GHz is 1.1549.

Thus, the values obtained are good enough as they are quite close to 1. The obtained values of both the parameters and the frequency values make the proposed antenna suitable for multiband applications.

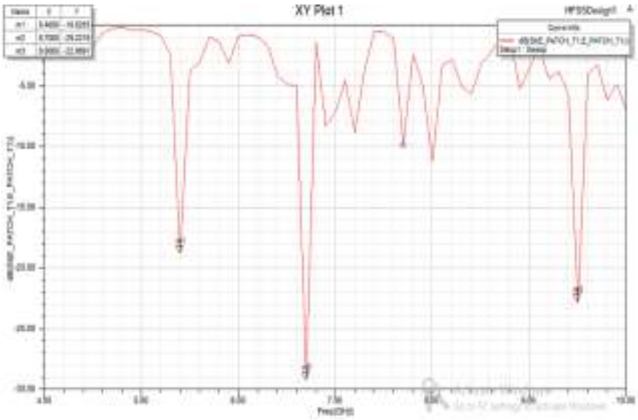

Figure3. S_{11} parameter results in HFSS

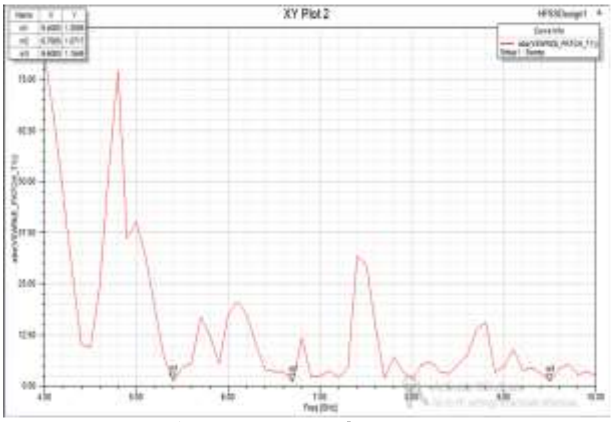

Figure4. VSWR results in HFSS

The values of other parameters like peak directivity, incident power, radiated power, peak gain at the resonant frequencies have been shown in Table 2 a,b,c respectively.

Table2(a). Antenna Parameters at 5.4GHz

S.No.	Parameter	Value
1	Frequency	5.4GHz
2	Max U	4.141998 mW/sr
3	Peak Directivity	5.761428
4	Peak Gain	5.274186
5	Peak Realized Gain	5.205111
6	Radiated Power	9.034410 mW
7	Accepted Power	9.869031 mW
8	Incident Power	10.000000 mW
9	Radiation Efficiency	0.915430
10	Front to Back Ratio	40.815142
11	Decay Factor	0.000000

Table2(b). Antenna Parameters at 6.7GHz

S.No.	Parameter	Value
1	Frequency	6.7GHz
2	Max U	5.325152 mW/sr
3	Peak Directivity	7.653389
4	Peak Gain	6.699956
5	Peak Realized Gain	6.691942
6	Radiated Power	8.743763 mW

7	Accepted Power	9.988038 mW
8	Incident Power	10.000000 mW
9	Radiation Efficiency	0.875423
10	Front to Back Ratio	98.196411
11	Decay Factor	0.000000

Table2(c). Antenna Parameters at 9.5GHz

S.No.	Parameter	Value
1	Frequency	9.5GHz
2	Max U	6.497764 mW/sr
3	Peak Directivity	8.164988
4	Peak Gain	8.207920
5	Peak Realized Gain	8.165524
6	Radiated Power	10.000656 mW
7	Accepted Power	9.948347 mW
8	Incident Power	10.000000 mW
9	Radiation Efficiency	1.005258
10	Front to Back Ratio	77.803623
11	Decay Factor	0.000000

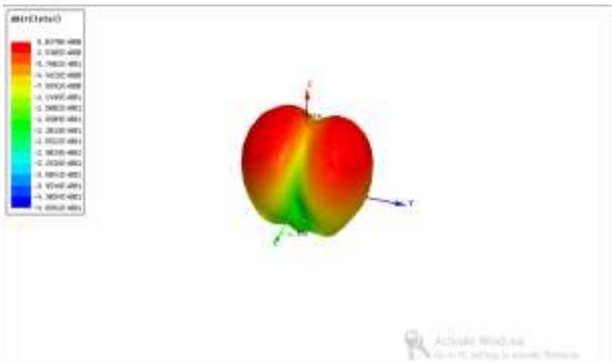

Figure5 (a). 3-D Polar Radiation plot at 5.4GHz.

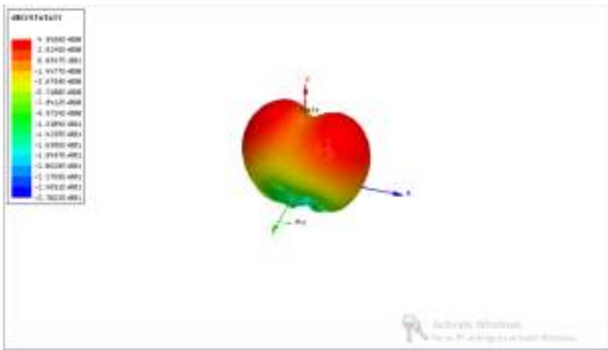

Figure5 (b). 3-D Polar Radiation plot at 6.7GHz.

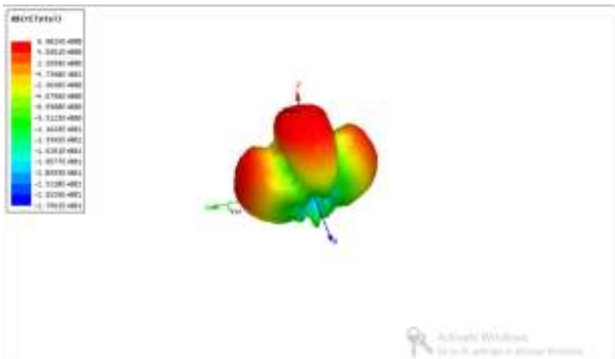

Figure5 (c). 3-D Polar Radiation plot at 9.5GHz.

The 3-D radiation plots at the three resonant frequencies are also shown in figures 5(a),(b)and (c). The 2-D E-θ radiation patterns for Ø= 90 and 0 degrees at different frequencies are shown in figures 6 (a),(b) and (c).

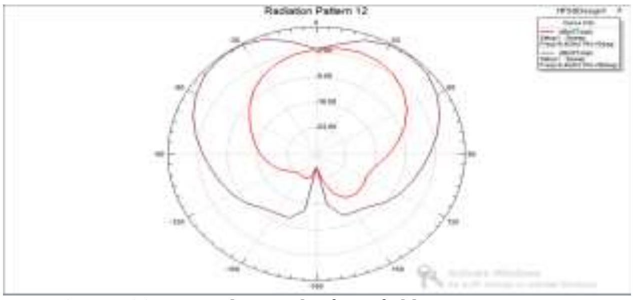

Figure 6(a). 2-D Radiation plot for E-field at 5.4GHz.

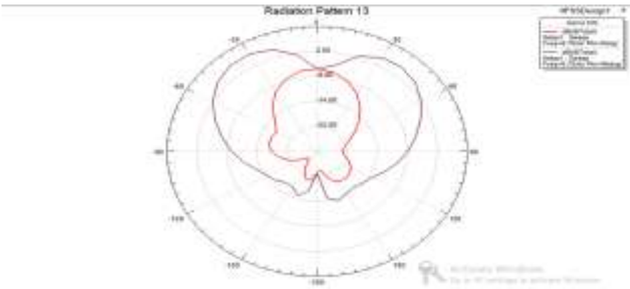

Figure 6(b). 2-D Radiation plot for E-field at 6.7GHz.

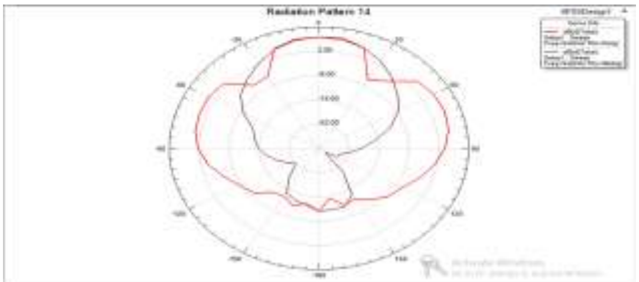

Figure 6(b). 2-D Radiation plot for E-field at 9.5GHz

IV. CONCLUSION

The antenna designed in HFSS thus has three resonant frequencies of 5.4 GHz, 6.7 GHz and 9.5 GHz with a return loss of -18.8 dB, -29.2 dB and -22.8 dB respectively and peak realized gain of 5.2 dB, 6.69 dB and 8.16 dB respectively. Thus, with such optimum parameters , it is suitable for various wireless communication applications in C and X region like WLAN, HIPERLAN, radar altimeter and defence applications. Further, other design changes to increase directivity and bandwidth can be incorporated into this design to increase its range of applications.

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