2016 1stInternational Electrical Engineering Congress(IEEC 2016)
May. 13-14, 2016 in IEP Centre,Karachi, Pakistan

Comparative Analysis of Different Patch Antennas

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Abstract: We make comparative analysis of important features of different structures of patch antennas at 2.4 GHz and study the effect of the patch structure. The microstrip patch antenna offers the advantages of compact size, conformability to any shape, ease of fabrication, and compatibility with integrated circuit technology. However, its properties change with the geometry of the antenna. In this work, we make comparative analysis of different antenna shapes on the basis of theirreturn loss/s-parameter, Voltage Standing Wave Ratio and far-field radiation pattern. These features may vary from one antenna to other depending upon the different geometric shape of the patch antenna.In this work, we study four antenna of different shapes i.e. Rectangular, U-shaped, S-shaped& E-shaped. Considering these relevant designs of microstrip patch antenna, these proposed with the four different shapes of the metamaterial structure. This paper evaluates variations in the antenna properties due to change in shape of the patch keeping the material of the patch antenna is same.

Keywords: Geometry of patch antenna, Rectangular, U-shaped, S-shaped, E-shaped, CST MW Studio

I. INTRODUCTION

At the present time the modern communication systems require microwave components with high performanceand small size, so compact antennas are essential. Metamaterial based antennas have potential to operate at very small size. Metamaterials are engineered structures whose properties can be controlled by changing the physical geometry [1]. The advantages of using metamaterial based antennas include lower fabrication cost, supporting both linear and circular polarization along with lower weight and volume etc. Despite of various advantages, there are certain disadvantages such as narrow bandwidth, lower efficiency and gain etc. In order to overcome these disadvantages there are certain ways that include changing the dielectric constant of material, changing the thickness of substrate material, stacking, changing the shape of patch etc [2].

Patch antennas are planar antenna variously used inwireless links and other microwave applications. TheMicrostrip antennas use conductive stripsand/or patches formed on the top surface of a thindielectric substrate separating them from a conductivelayer on the bottom surface of the substrate andconstituting a ground for the line [3]. The basic structural model of microstrip patch antenna is shown in Fig. 1. [4]The design of such smaller size antenna systems are able to satisfy the standard of sharing the license-free industrial, scientific,and medical (ISM) frequency which is at 2.4 GHz.

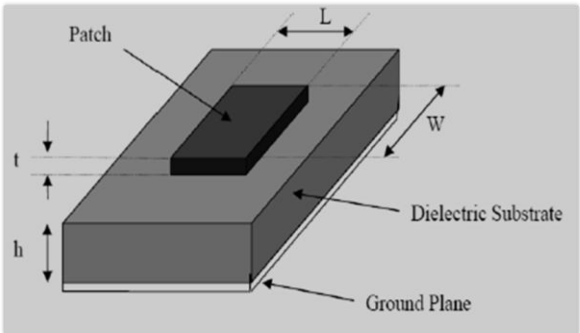


Fig. 1 The basic structural model of microstrip patch antenna.

In this paper we study the effect of geometry of the antenna on important parameter such as return loss, VSWR and far-field radiation pattern. We compare four types of patch antennas i.e. rectangular, U-shaped, S-shaped and E-shaped patch antennas. All the antennaswe compare are inset feed patch antenna. These type of antennas acts approximately as a resonant cavity. When the antenna is excited at resonant frequency, a strong field is created inside the cavity whereas a strong current is created on the surface of patch resulting in high radiation at the resonant frequency. We observe that the properties of the antennas are strongly dependent on the antenna geometry. Therefore, any specific property may be optimized by changing the geometry of the antenna.

Rest of the paper is arranged as follows. Section II summarizes the simulation set up. In section III we describe the physical geometries of different types of antennas used in the study. In section IV we compare the simulation results for different types of the antennas. In Section V conclude the paper.

II. SIMULATION SET UP

The proposed patch antennas are simulated by Finite Integration Technique based software package CST Microwave Studio. The software package is commonly used by the research community to perform similar studies. The geometry of the patch is defined using the built-in geometry tools of CST microwave studio. The substrate used in RT/Duroid 5870 as substrate which has a dielectric constant of 2.33 and a thickness of 0.787mm. The metallic ground as well as the antenna itself is made of copper. A vies of the simulation environment is shown in Fig. 2. We use waveguide port at inset feed to excite the antenna and the boundary conditions used for the antenna radiation are shown in Fig. 2. An auto-meshing algorithm of CST was used to generate the tetrahedral mesh for the numerical computation.

The simulation of different geometric shapes evaluates return loss/s-parameter, Voltage Standing Wave Ratio and far-field radiation pattern at 2.4 GHz. These features may vary from one antenna to other depending upon the different geometric shape of the patch antenna.

III. ANTENNA GEOMETRY

The material of the patch antennas is resonates on a RT/Duroid 5870 as substrate. The ground of the antenna is on Copper(annealed) material which is same for all geometric shape having thickness of 0.07 mm. The geometric parameter of rectangular shaped, U-shaped, S-shaped, and E-shaped antennas shown in Fig. 3, 4, 5, & 6 are summarized in Table 1, 2, 3, & 4 respectively.

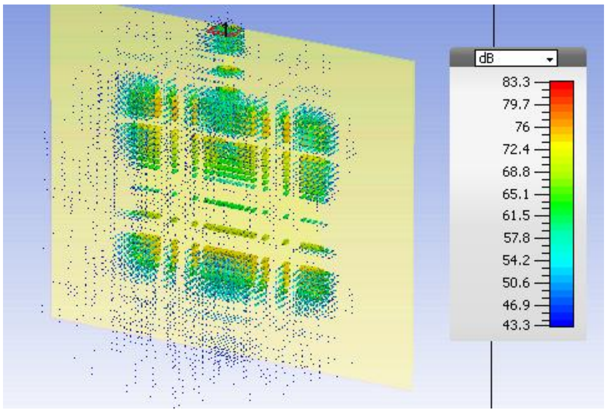


Fig. 2 Radiation under the boundary condition of the rectangular patch

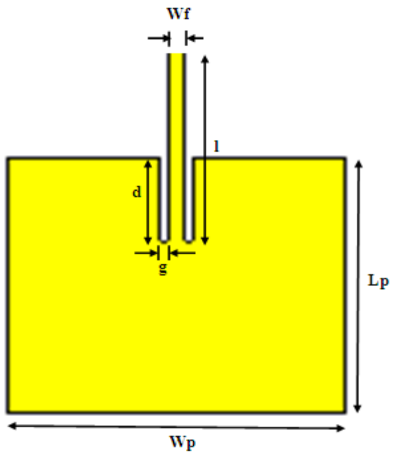


Fig. 3 Geometry of rectangular patch antenna

Table 1 Parameters for Rectangular Patch Antenna

Parameters	Description	Value
Wp	Width of Patch	47mm
Lp	Length of Patch	39 mm
Wf	Width of Feed	2.3mm
d	Distance of Inset Feed	12.7mm
l	Length of Microstrip Feed	32mm
g	Gap between Microstrip Feed and Patch	1mm

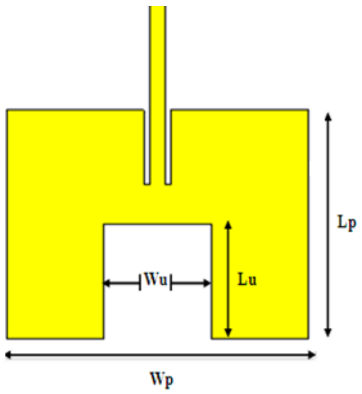


Fig. 4 Geometry of U-shaped patch antenna

Table 2 Parameters for U-shaped Patch Antenna

Parameters	Description	Value
Wp	Width of Patch	47 mm
Lp	Length of Patch	39 mm
Wu	Width of U slot	19 mm
Lu	Length of U slot	17 mm

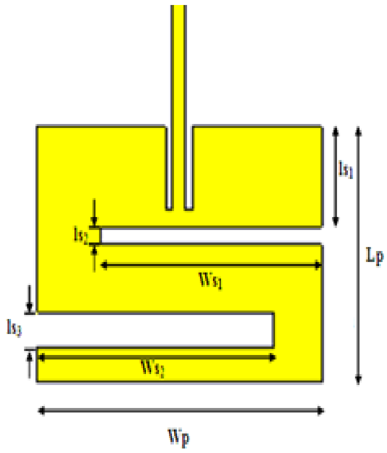


Fig. 5 Geometry of S-shaped patch antenna

Table 3 Parameters for S-Shaped Patch Antenna

Parameters	Description	Value
Wp	Width of Patch	47 mm
Lp	Length of Patch	39 mm
ls_1	Length of S Slot	28 mm
ls_2	Length of S Slot Gap1	3 mm
ls_3	Length of S Slot Gap2	4 mm
Ws_1	Width of S slot	37 mm
Ws_2	Width of Second S Slot	37 mm

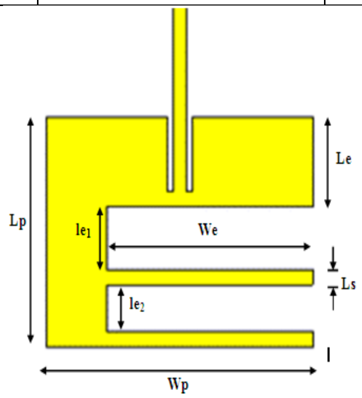


Fig. 6 Geometry of E-shaped patch antenna

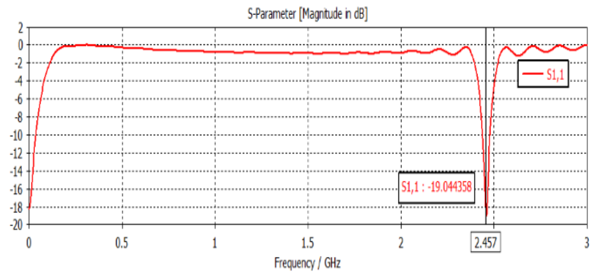
Table 4 Parameters for E-shaped Patch Antenna

Parameters	Description	Value
Wp	Width of Patch	47 mm
Lp	Length of Patch	39 mm
We	Width of E slot	36 mm
Le	Length of E slot with feed	17 mm
le_1	Length of gap in E slot1	10 mm
le_2	Length of gap in E slot2	8 mm
Ls	Length of E slot	2 mm

IV. ANTENNA COMPARISION

A. S_{11} or Return Loss Comparison

The *S*-parameters describe the relationship between input and output power at different ports/ terminals of an electrical system. In antenna theory the most commonly used parameter is S_{11} which describes the ratio of reflected power at the input terminal to the antenna and hence used to define return loss of the antenna. Fig. 7, shows the comparative analysis of S_{11} parameter in the patch antennas under study. Table 5 summarizes the S_{11} for all antenna geometries at their respective resonant frequencies. Considering the overall result to the relevant proposed structure of antennas the E-shaped patch antenna gives minimum value of S_{11}(i.e. -24.62 dB at 2.13 GHz) and hence high radiation gain, in comparison of other patch antenna.



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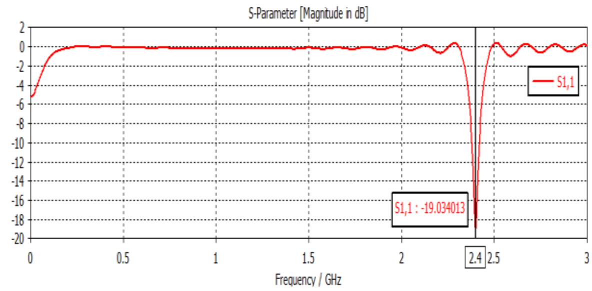

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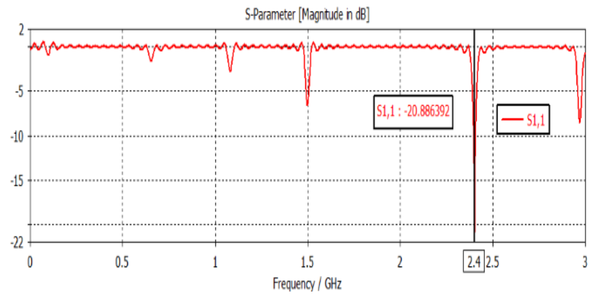

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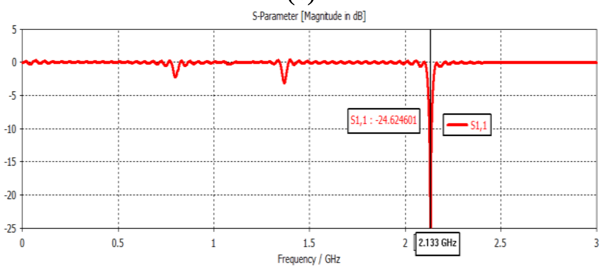


(d)

Fig. 7 the S_{11} result of all four patch antenna. (a) Rectangular patch antenna (b) U-shaped patch antenna (c) S-shaped patch antenna (d) E-shaped patch antenna

Table 5 S_{11} Parameter

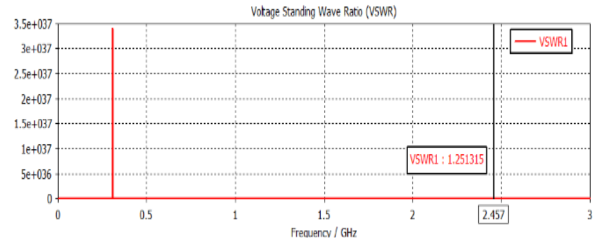
Antenna	S_{11}
Rectangular	-19.04 dB at 2.45 GHz
U-Shaped	-19.03 dB at 2.4 GHz
S-Shaped	-20.89 dB at 2.4 GHz
E-Shaped	-24.62 dB at 2.13 GHz

Table 6 VSWR

Type of Antenna	VSWR
Rectangular	1.25 at 2.457 GHz
U-Shaped	1.252 at 2.4 GHz
S-Shaped	1.19 at 2.4 GHz
E-Shaped	1.126 at 2.133 GHz

B. VSWR Comparison

VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna due to impedance mismatching. The value of VSWR or SWR must be close to unity for maximum power transfer and better impedance matching. The comparative analyses VSWR of all four antennas are shown inFig.8. From the Table 6 we find that E-shaped antennas give us the better result i.e. 1.126 among other antennas.



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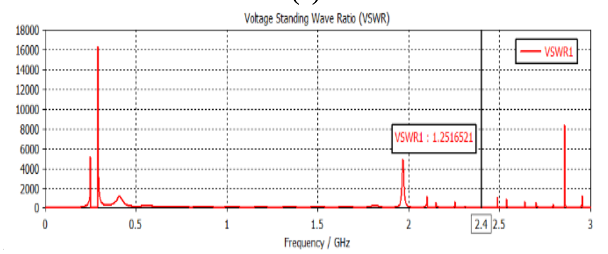

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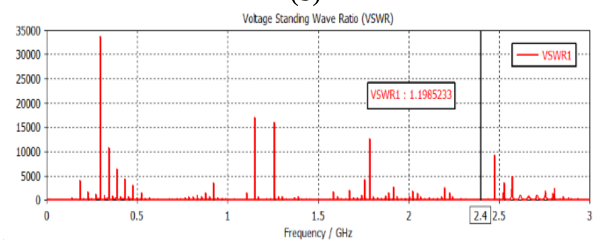

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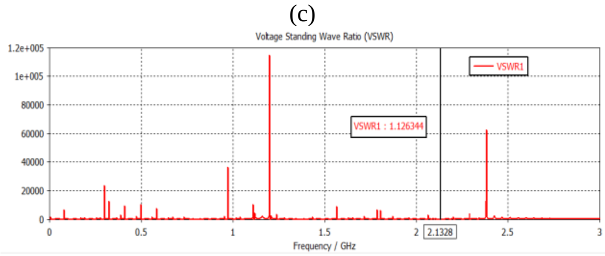

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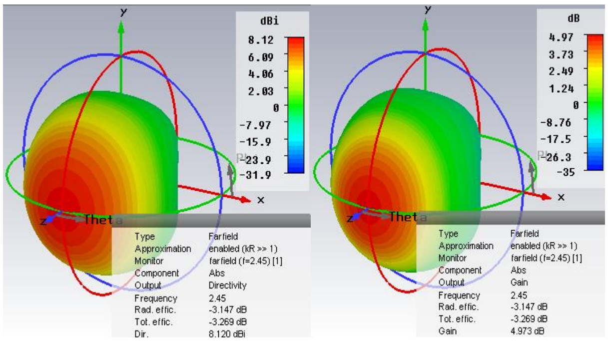
Fig. 8 the VSWR of all four patch antenna. (a) Rectangular patch antenna (b) U-shaped patch antenna (c) S-shaped patch antenna (d) E-shaped patch antenna

C. Far-Field Radiation Pattern Comparison

The 3D result of far-field radiation pattern shown in Fig. 9. The directivity and gain of each of the antenna is summarized in Table 7. It is observed that the U-shaped antenna has highest directivity and gain.



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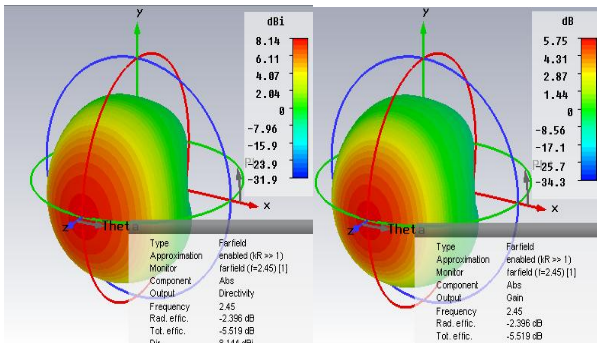

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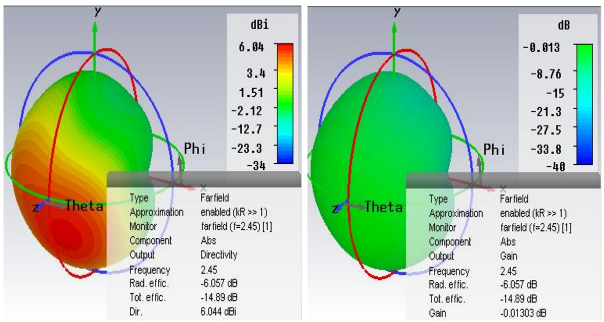

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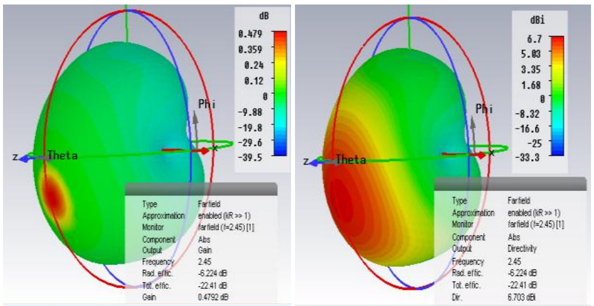

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Fig. 9 The Far-Field Radiation Pattern of Directivity & Gain of all four patch antenna. (a) Rectangular patch antenna (b) U-shaped patch antenna (c) S-shaped patch antenna (d) E-shaped patch antenna

Table 7Directivity and gains of the antennas

Antenna	Directivity (dBi)	Gain (dB)
Rectangular	8.12	4.97
U-shaped	8.14	5.75
S-shaped	6.04	-0.013
E-shaped	6.703	0.4792

V. CONCLUSION

In this paper we study and compare important parameter of different types of the patch antenna. It is observed that changing geometry of the patch antenna significantly changes different parameters of the patch antenna. Hence, changing geometry of the patch antenna can help improving some of the parameters on the cost of degrading others.

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