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Comparative Analysis of Microstrip patch antenna arrays for S band applications

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Abstract: This paper presents a comparative analysis of 2×2 antenna array of rectangular topology, U-slot and E- slot microstrip patch antenna array . The operating frequency of array is 2 to 4 GHz. The antenna arrays have been designed and simulated on Rogers RO4350 (tm) substrate with a dielectric constant of 3.66. This paper presents that, the performance of antenna array is improved after the slot cutting in the patch of antenna. The design is analyzed by FEM based HFSSv11 by which return loss, 3D polar plot, VSWR, gain and radiated power of the antenna arrays are computed. The software simulated results shows that the E slot antenna array provides good performance as compared to U slot antenna array and rectangular patch antenna array with the return loss value of -36.082dB at 2.41GHz and VSWR value 0.2727 at the same frequency.

Keywords: Microstrip patch antenna, HFSS, return loss, VSWR, 3D polar plot, gain, directivity.

I. INTRODUCTION

Antennas play a very important role in modern communication systems, as they are the most important components to create a communication link .Microstrip patch antennas are widely used in communication systems because of, they are low profile, of light weight, of low volume, having low fabrication cost, conformal design, low power handling capacity, can be easily integrated with microwave integrated circuits (MICs), supports linear as well as circular polarization. They can be designed in a variety of shapes in order to obtain enhanced gain and bandwidth [1].

Antenna array is a set of multiple connected antennas and arranged in a regular structure to form a single antenna. Phased array antenna is a multiple antenna system in which the direction of maximum transmission or reception can be altered by electrical switching means. In these arrays, the radiated energy is highly concentrated in a particular direction and strongly suppressed for other directions [2].

The major advantages of antenna arrays are:

- An antenna array can achieve higher gain and directivity, than could be achieved by a single antenna.
- Arrays can be used to give path diversity (also called MIMO) by exploiting multipath propagation to multiply link capacity.
- They can be used for interference suppression and to achieve many other signal processing functions like spatial filtering, target tracking etc.
- Arrays are generally used for radio direction finding (RDF) [3], [4].

Slot antenna is an important configuration among all the various existing configurations in communication system. It consists of a metal surface, with one or more holes or slots cut out. When the plate is driven as an antenna by a driving frequency, the slot radiates electromagnetic waves in a way similar to a dipole antenna.

Slot antennas are widely used in radar and satellite communications, which is an application of S band spectrum. Slotted antennas are generally used at UHF and microwave frequencies. A slot antenna's main advantages are its size, design simplicity and it is capable of dual and triple frequency operations .

The proposed antenna array is suitable for various modern wireless communication system applications like WiMax Services, RADAR, fixed satellite services operating in the frequency range of 2-4 GHz where antenna with low profile, small size, light weight and broad pattern is required.

II. DESIGN CONSIDERATIONS

TABLE 1: Design Parameters and corresponding values

Design Parameters	*Value*
Operating frequency	**2-4 GHz**
Dielectric constant of substrate	**3.66**
Length of the substrate	**71mm**
Width of the substrate	**52mm**
Length of the patch	**35.5mm**
Width of the patch	**26mm**
Array size	**2×2**
Radius of coax pin	**0.7mm**
Height of the coax pin	**5mm**

The above design considerations are same for all the three antenna arrays. These values are calculated by finite element modeling (FEM). Finite element modeling (FEM) is a powerful computational technique or we can say, a numerical method, to attain the solution of differential and integral equations [5],[6]. FEM models provide good results in quick time with accurate solutions by solving multiple differential equations using piecewise approximation [7].

A. *Design of rectangular microstrip patch antenna array*

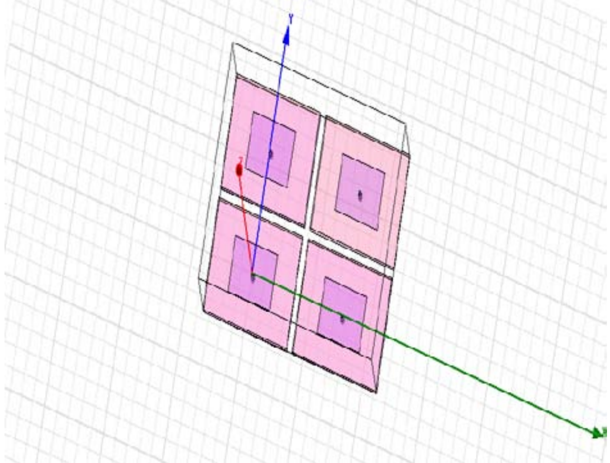

Fig.1: 2×2 Rectangular microstrip patch antenna array design (original image from HFSSv11)

The above figure represents 2×2 rectangular microstrip patch antenna array design. The method used to analyze antenna is FEM (Finite Element Modeling) and the feeding technique used is **Probe Feeding.** The spacing between elements is **5mm.**

Simulation results using HFSS:

The below figures represent various results like Return loss, VSWR, 3D Polar plot, radiation pattern during simulation-

1) *Return loss:*

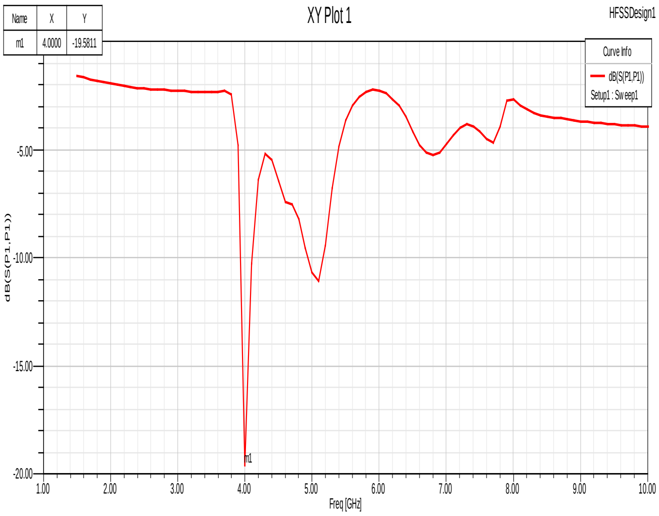

Fig.2: Return loss of 2×2 rectangular microstrip antenna array

Figure 2 represents the return loss of -19.5811db at the frequency of 4 GHz.

2) *VSWR:*

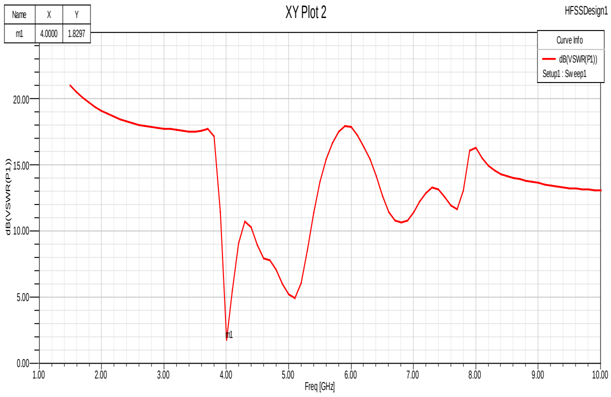

Fig.3: VSWR of 2×2 rectangular microstrip antenna array

Figure no.3 represents the VSWR of 1.8297 for the corresponding frequency of 4GHz.

3) *3D Polar plot:*

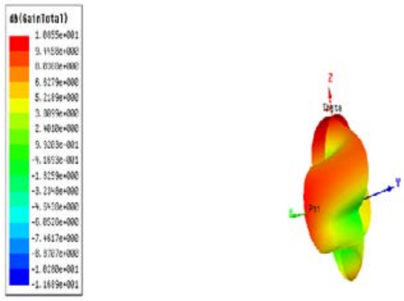

Fig.4: 3D polar plot of 2×2 rectangular microstrip antenna array

The above figure represents the gain of 1.6355 dB for the rectangular patch antenna array.

4) *Radiation pattern*

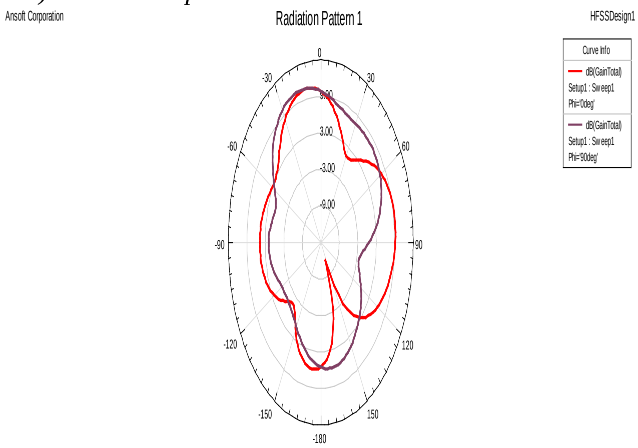

Fig.5: Radiation pattern of 2×2 rectangular microstrip antenna array

B. Design of U slot microstrip patch antenna array

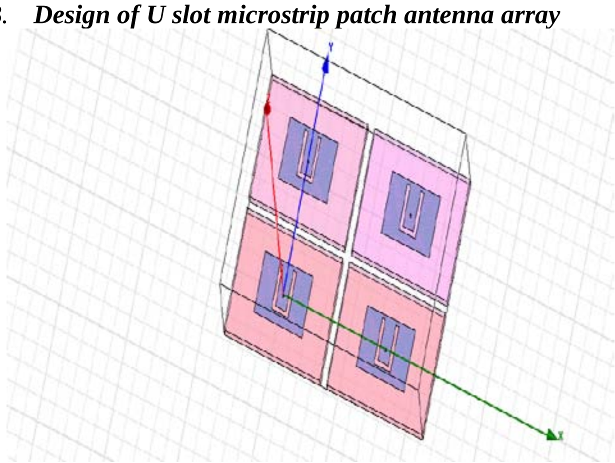

Fig.6: 2×2 U slot Microstrip patch antenna array design

Simulation results using HFSS:

1) Return loss:

The graph for return loss of U slot microstrip patch antnna array is shown in next figure(Fig.7).

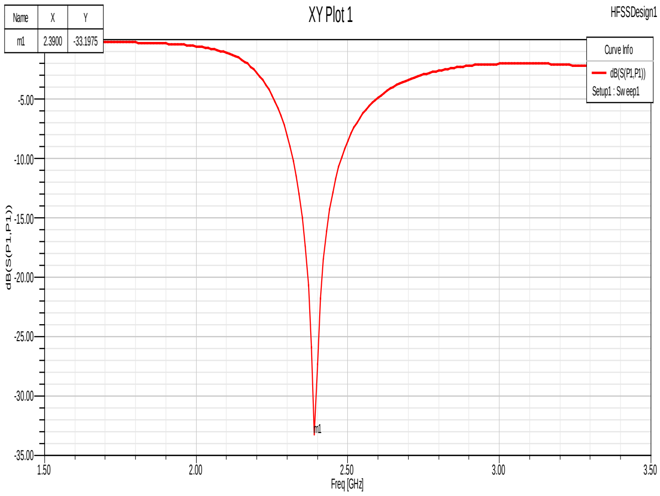

Fig.7: Return loss of 2×2 U slot microstrip antenna array

The above figure represents the value of return loss which is equal to -33.1975 db at the frequency of 2.39 GHz.

2) VSWR:

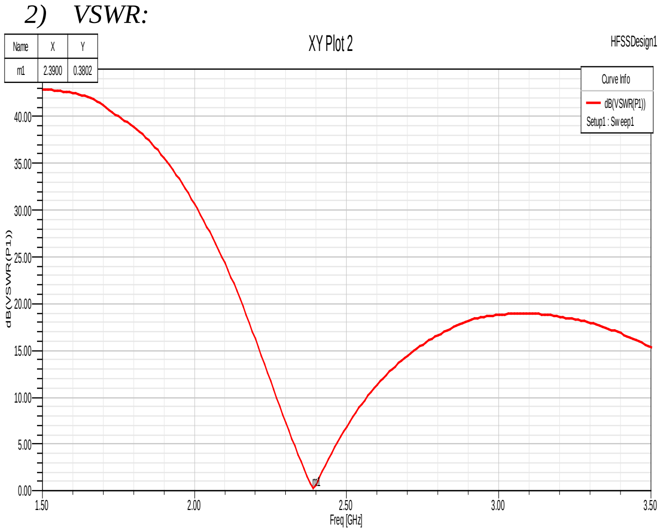

Fig.8: VSWR of 2×2 U slot microstrip antenna array

The value of VSWR corresponding to the frequency of 2.39GHz is 0.3802 which is a much improved value as compared to VSWR of rectangular microstrip patch antenna array.

3) 3D polar plot:

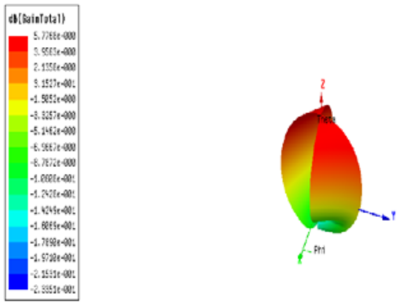

Fig.9: 3D Polar plot of 2×2 U slot microstrip antenna array

This figure represents the value of gain attained by U slot microstrip patch antenna array which is 5.013 dB . This value is very high as compared to the gain attained by rectangular patch microstrip antenna array.

4) diation pattern:

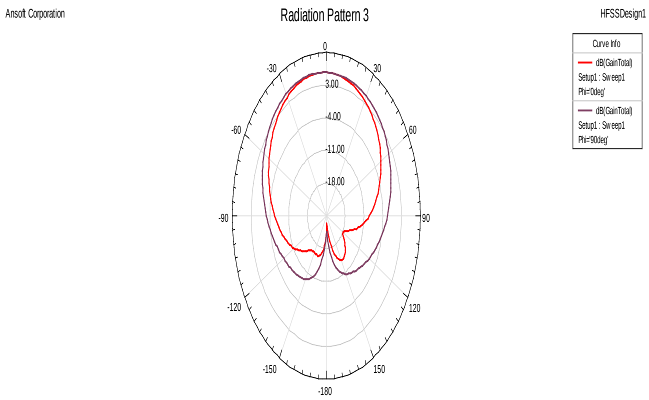

Fig.10: Radiation pattern of 2×2 U slot microstrip antenna array

The simulation result shows that the performance of antenna array improves after cutting a U slot in each antenna of the array.

C. Design of E slot microstrip patch antenna array

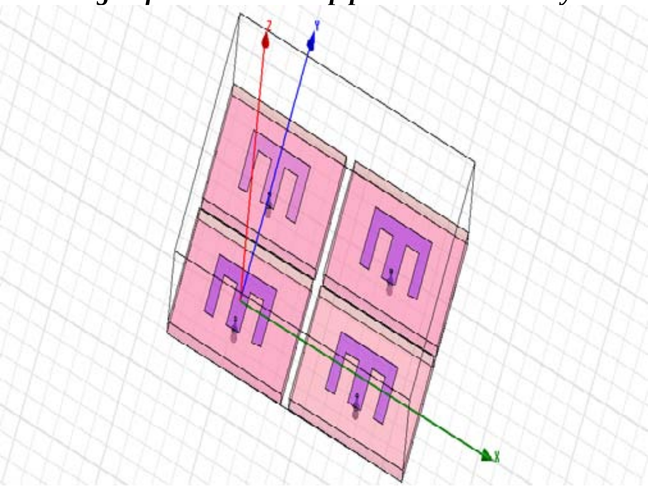

Fig.11: 2×2 E slot microstrip antenna array design

Simulation results using HFSS:

1) Return loss:

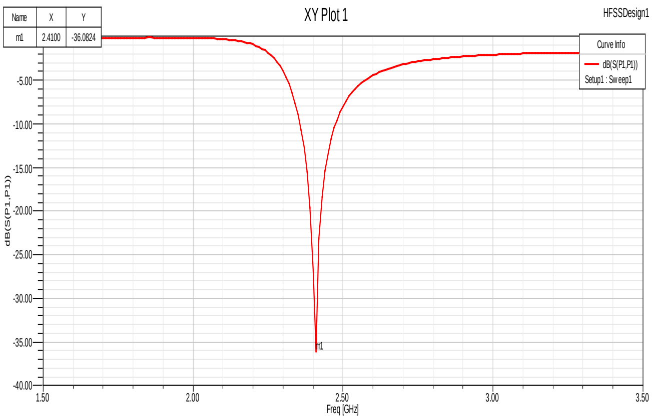

Fig.12: Return loss of 2×2 E- slot microstrip patch antenna array

The above figure represents the value of return loss for 2×2 E slot microstrip patch antenna array design and it is equal to -36.082db at 2.41GHz.

2) VSWR:

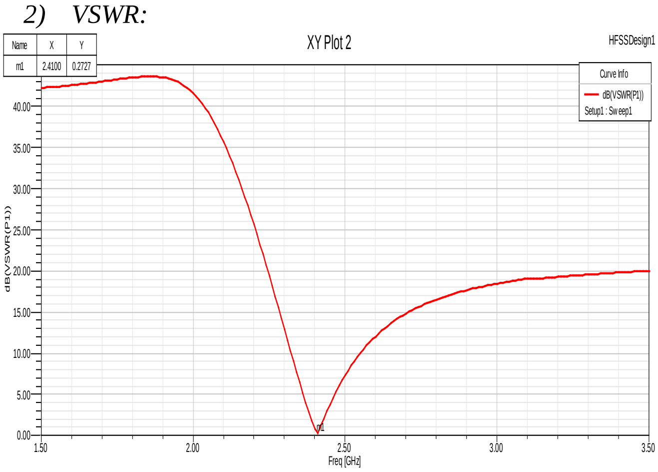

Fig.13: VSWR of 2×2 E-slot microstrip patch antenna array

The value of VSWR corresponding to the frequency of 2.41GHz is 0.2727 which is an improved value as compared to VSWR of U slot microstrip patch antenna array.

3) 3D Polar plot:

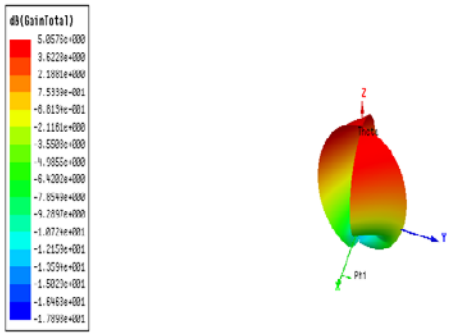

Fig.14: 3D Polar plot of 2×2 E slot microstrip antenna array

This figure represents the value of gain attained by E slot microstrip patch antenna array which is 5.855 dB.

4) Radiation pattern:

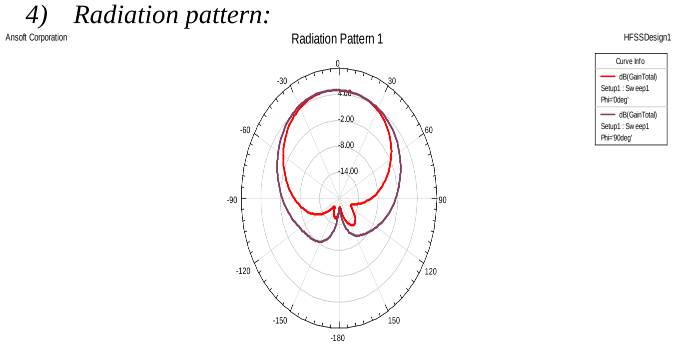

Fig.15: Radiation pattern of 2×2 E slot microstrip patch antenna array

The simulation results indicate that 2×2 E slot antenna array has better performance in terms of return loss, VSWR, gain and directivity as compared to 2×2 U slot microstrip antenna array. Here, with the help of a comparison table, a comparison is made between the three arrays performance parameters such as return loss, VSWR, gain and radiated power.

TABLE 2: Comparison table

Performance Parameters	*Rectangular patch*	*U slot*	*E slot*
Return loss(dB)	-19.5811	-33.1975	-36.082
VSWR	1.8297	0.3802	0.2727
Gain(dB)	1.6355	5.013	5.855
Radiated power(W)	0.0784	0.9185	0.9563

The comparison table shows that E slot antenna array has better results than U slot and rectangular patch antenna array.

III. COMPARISON GRAPHS:

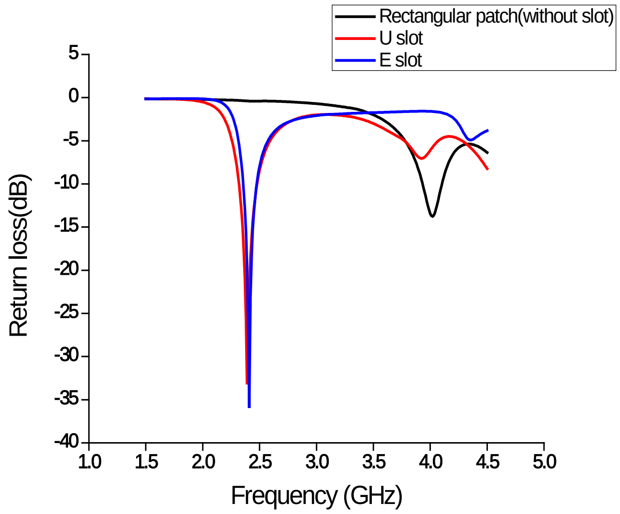

Fig.16: Showing variation in the return loss values of the three antenna arrays

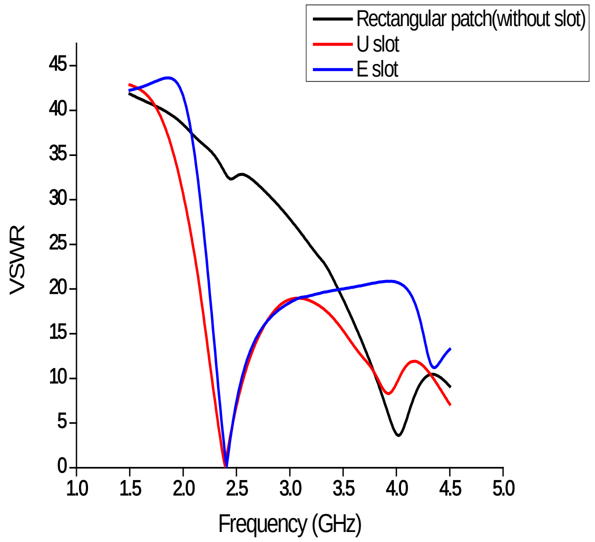

Fig.17: Showing variation in the VSWR of the three antenna arrays

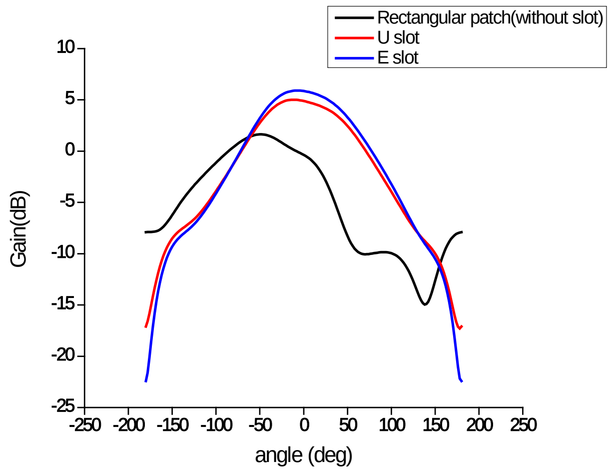

Fig.18: Showing variation in the gain values of the three antenna arrays

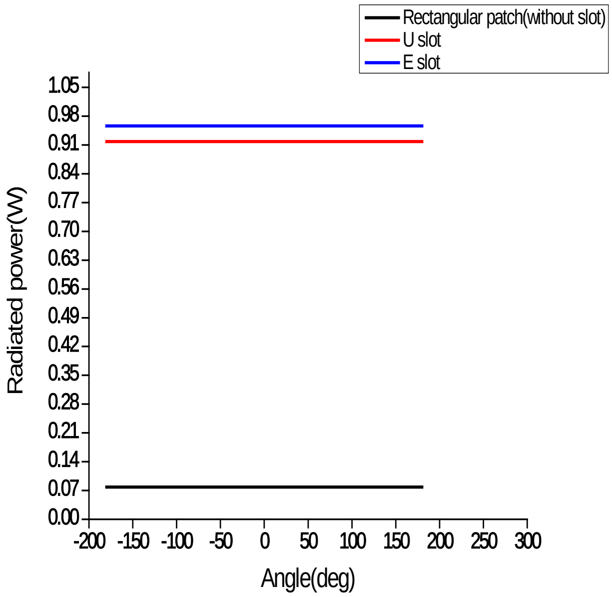

Fig.19: Showing variation in the radiated power of the three antenna arrays

IV. CONCLUSION

In this paper, a comparative analysis of the three antenna arrays having the same size and design considerations, is presented. The simulation results indicates that the E slot antenna array has better results as compared to rectangular patch antenna array and U slot antenna array. E slot antenna array has return loss value -36.082dB at 2.41GHz, VSWR value is 0.2727 and gain is 5.855 dB.

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