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An X-Band based 2 X 1 Microstrip Antenna Array with Combined H and Dual U Slot Design Operating at 11 GHz Frequency

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ABSTRACT
In this paper, microstrip antenna array is considered. The resolution of the array is considered to be (2X1). The dimensions of the proposed antenna (width and length in 'mm') are taken as 8.3 mm x 5.75 mm. Also to improve the radiation properties combined H and dual U slots are cut on the antenna array elements. The theoretical calculations are done according to the considered dimension parameters using the standard patch antenna parameters, where the resonant frequency is found out to be "11 GHz". Now the proposed antenna is simulated using HFSS software. The ground plane is considered with the dimensions 26 mm x 16 mm. The dielectric is taken to be FR4 epoxy substrate. Strip-line feeding (inset-fed) is used to feed the antenna array. The simulated results showed the proposed antenna to be working at 11.03 GHz with return loss of -31.10 dB and a VSWR of '1.05'. Also the results are compared with the H slot microstrip antenna array and the dual U slot microstrip antenna array. All the necessary findings are tabulated and plotted.

General Terms
Antenna Performance, Gain characteristics

Keywords
microstrip patch antenna, H slot, U slot, X band applications, strip-line feeding, inset feed, satellite applications, radar applications.

1. INTRODUCTION
In today's world of modern wireless industry, an antenna plays a vital role in placing a proper communication link. In order to withstand the huge competition all the wireless equipment manufacturers are in the need to design compact, low cost and small size antennas. The main reason behind this is to connect to the wireless connections wherever possible. Features such as Wi-Fi, LTE, Bluetooth and WiMAX are some of the examples where a user can be able to communicate on a wireless basis [1]. Microstrip antennas provide wide range of applications ranging from mobile industry to radar and satellite communications. In general, a simple microstrip antenna is made up of a conducting patch that is usually printed on substrate which is grounded.

These microstrip antennas also provide all the advantageous features which include less weight, low size and less fabrication costs. But the problem associated with conventional microstrip antenna is its narrow bandwidth [2]. Also to meet the needs of the low size mobile equipment, it is necessary to further miniaturize the microstrip antennas and also at the same to enhance the bandwidth. Another problem is the increasing demand for the wireless services in the urban regions where there will be several networks which coexist and operate simultaneously [3]. Therefore it is also necessary for these antennas to be operated in the multiband modes. This is achieved by the use of stubs and loading and also with the use of slots [4]. But the problem with stubs and loading is that they increase the antenna size and thickness. Therefore slots provide a better option in this regard. Various slot shapes such as L slot, E slot, T slots are proposed [5-7]. Slots prove advantageous as there will be flexibility in optimizing the structure according to the requirement. Other important design considerations such as stacked antenna which is probe fed, use of thick substrate, use of feeding and impedance matching technique also prove beneficial to overcome the limitation of narrow bandwidth [8-9]. When considering feeding a particular antenna, there are many ways proposed over the years for given necessary input to the antenna. This concept of feeding an antenna is of many types such as strip-line feeding, coaxial feeding, etc. in general when input impedance is the main criteria, to improve it inset feeding is implemented in the microstrip antennas. The use of H slot and u slot for the microstrip patch antenna is discussed in [11-14]. The X-band which ranges from 8GHz to 12 GHz frequencies provides vast applications in satellite and radar engineering. Radars which are operating in this range are generally used as police radars for measuring the speed of the vehicle and also more important use of these radars are found in military, navigation and in determining the weather forecast [15].

This research paper is divided into four parts. Section 1 deals with the necessary introduction, Section II explains about the proposed microstrip antenna design, deals with the considered microstrip patch antenna (MPA) array structures, Section III deals with simulation results and Section IV concludes the paper.

2. ANTENNA DESIGN

2.1 The Proposed Concept of Combined H and Dual U Slot Design
To increase the directional properties of the antenna, sometimes group of similar antennas are placed defined by a particular geometric configuration. This arrangement of multiple radiating antenna elements is termed as an array. In many cases small antennas are used as an array which obtains the performance levels similar when compared to a large antenna [10]. Arrays can be of different configurations such as linear, circular, planar circular, elliptical arrays, etc.

In the current paper, a (2X1) microstrip antenna array is taken into account. The ground plane is taken to be 26 mm x 16mm in dimension. On the ground place dielectric substrate is placed. FR4 epoxy is considered as the dielectric material with dielectric constant as '4.4' and loss tangent '0.02'. The

height of this dielectric substrate is taken to be '1.6 mm'. On the top of the dielectric substrate a conducting patch is placed.

The design parameters for calculating the length and the width of the proposed antenna are taken from the general microstrip patch antenna parameters considered in [1]. To improve the radiation properties of the microstrip patch antenna, combined H and U slots are along the patch. The configuration of H and U slot designs along with the proposed combined H and Dual U slot design is shown in the figure 1.

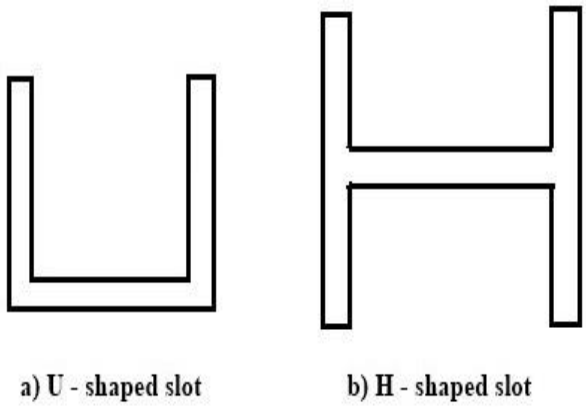

Fig.1 Considered MPA array slot designs

2.2 The H-Slot Microstrip Antenna Array and the Dual U-Slot Microstrip Antenna Array

Firstly, a conventional microstrip (2X1) patch antenna is designed and slot is cut in the H shape. The width and length of the patch antenna are considered to be 8.3 mm and 5.75 mm. The H slot is made in both the antennas; the measurements considered are shown in the figure 2. The microstrip patch antenna array with H slot is designed to operate at a frequency of 11 GHz. The figure 2 below depicts the considered (2X1) H slot patch antenna array.

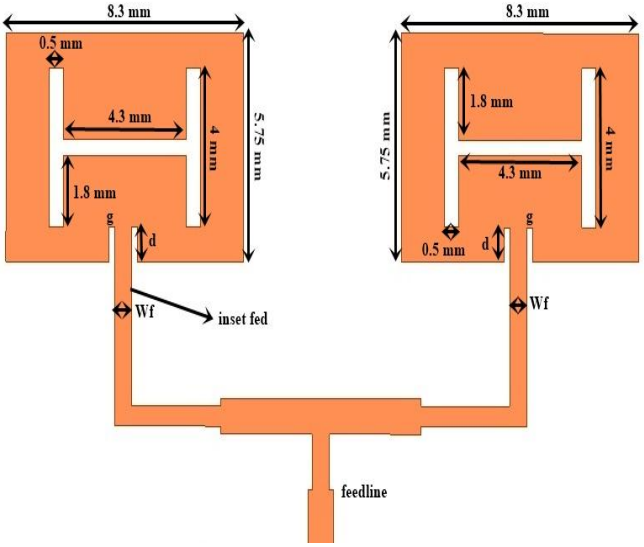

Fig.2 A (2X1) H Slot Design Microstrip Antenna Array

After the H slot antenna array is designed, now the dual U slot antenna array is designed. The microstrip antenna is shown in the figure 3.

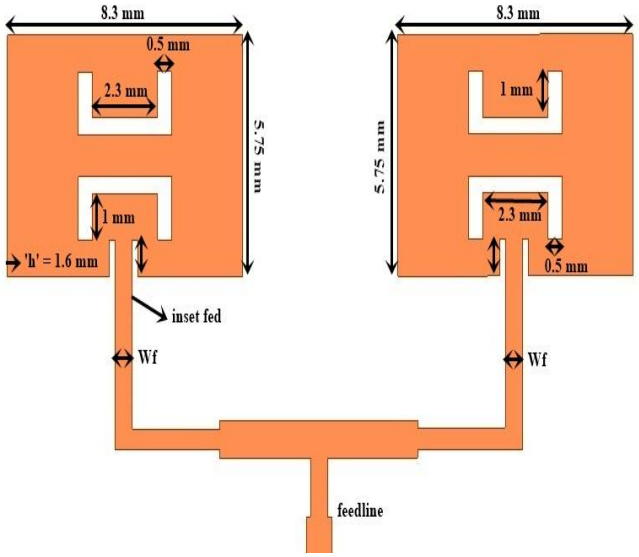

Fig.3 A (2X1) Dual U Slot Microstrip Antenna Array

3. THE PROPOSED MICROSTRIP ANTENNA ARRAY

The arrangement of combined H and dual U slot design is cut on the conducting patch antenna. The H slot is made at first and then two U slots are arranged in mirror form in the H slot. The proposed design with all the measurements is shown in the figure 4.

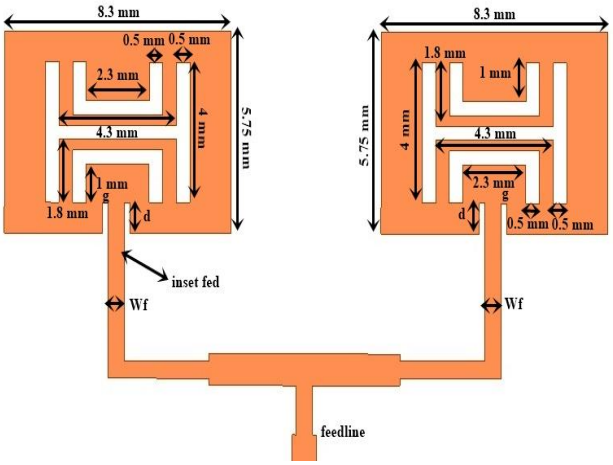

Fig.4 The Combined H and Dual U Slot Design (2X1) Microstrip Antenna Array

The given microstrip antenna array is fed with microstrip feeding (inset-fed) of 50Ω impedance. For any rectangular patch the current is concentrated minimum at the edges or ends of the patch and maximum towards the center. Therefore, by using the microstrip line (inset-fed) there are some advantages, the first one being the inset feeding feeds the given patch antenna directly near to the center and second advantage being offering of high input impedance. The proposed antenna is considered to operate at 11 GHz frequency

4. SIMULATION AND RESULTS

4.1 The H slot MPA Array

The theoretical calculation with respect to considered width and length obtained a resonant frequency of 11 GHz for the considered microstrip patch antenna. Now the simulation part is done using HFSS software.

Firstly, the H slot antenna array is considered. The return loss is calculated first. The H slot microstrip antenna array achieved a resonant frequency of 11.18 GHz after the simulation in HFSS. The return loss observed was -23.58 dB. The return loss curve with the resonant frequency of 11.18 GHz is shown in the figure 5.

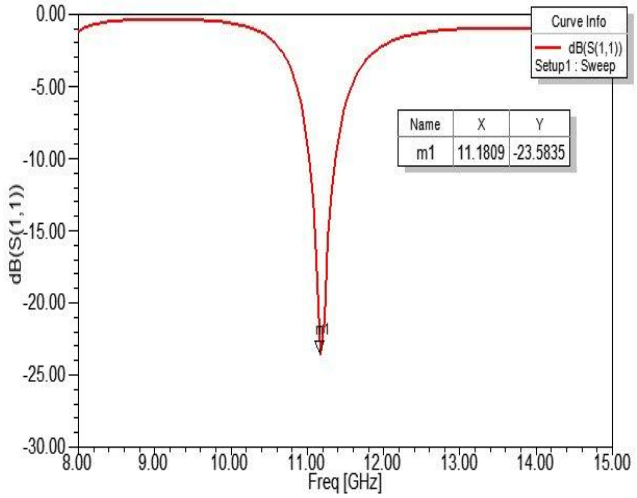

Fig.5 The return loss versus frequency curve for the H slot MPA array

The Voltage wave standing ratio in this case is found out to be 1.1418. Since the VSWR should be less than the value of 2, the obtained VSWR value is proved to be good for the efficient working of the antenna array. The VSWR plot is shown in the figure 6.

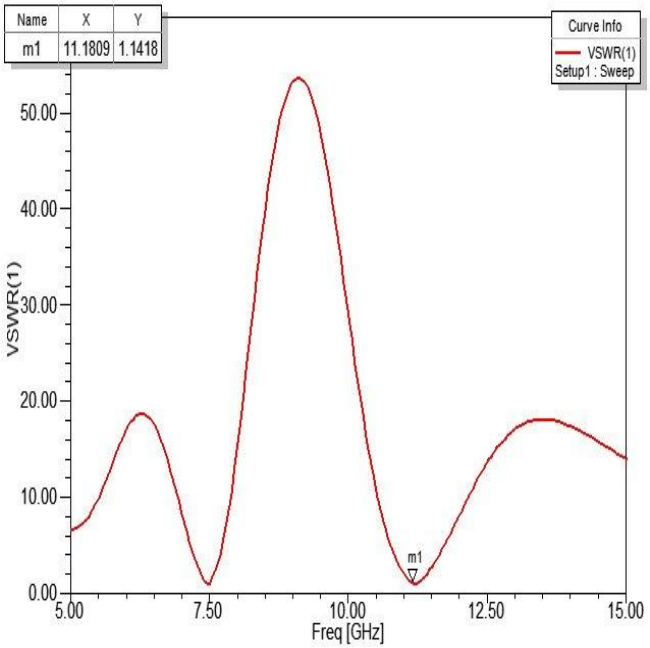

Fig.6 The VSWR plot for the H slot MPA array

The 3D polar is created to show the radiation properties of the H slot MPA. The figure is given in the below figure 7.

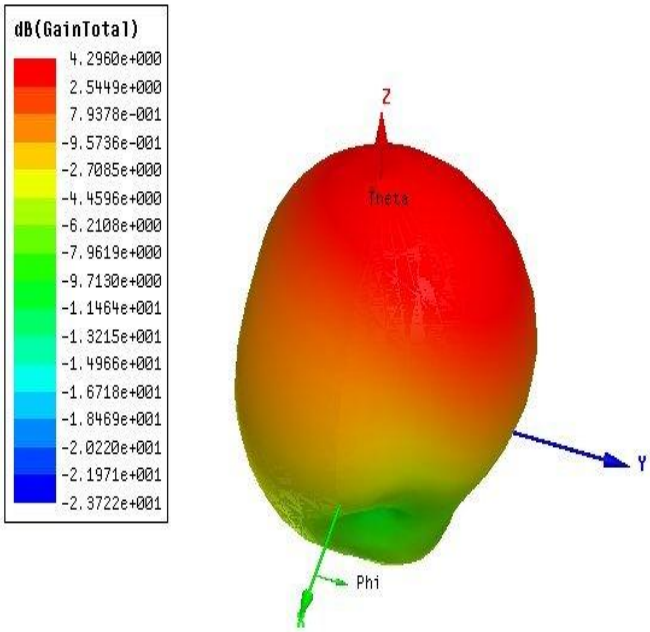

Fig.7 The 3D polar plot showing the gain characteristics of H slot MPA array

4.2 The Dual U slot MPA Array

Now the Dual U slot MPA is considered. The simulated return loss is this case for the same antenna parameters considered is said to be obtained a value of -18.01 dB for a resonant frequency of 11.5 GHz. The plot is shown in figure 8.

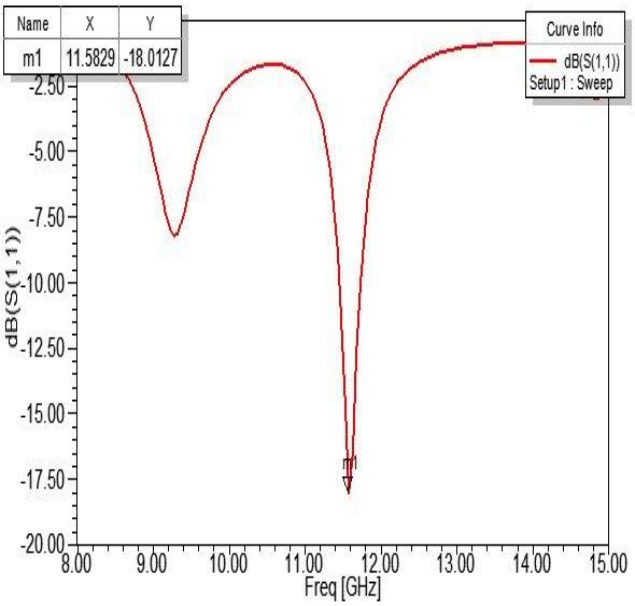

Fig.8 The return loss versus frequency curve for the Dual U slot MPA array

The Voltage wave standing ratio in this case is found out to be 1.2876. The obtained VSWR value is also below 2. The VSWR plot is shown in the figure 9. And the radiation characteristics plot is given in the figure 10.

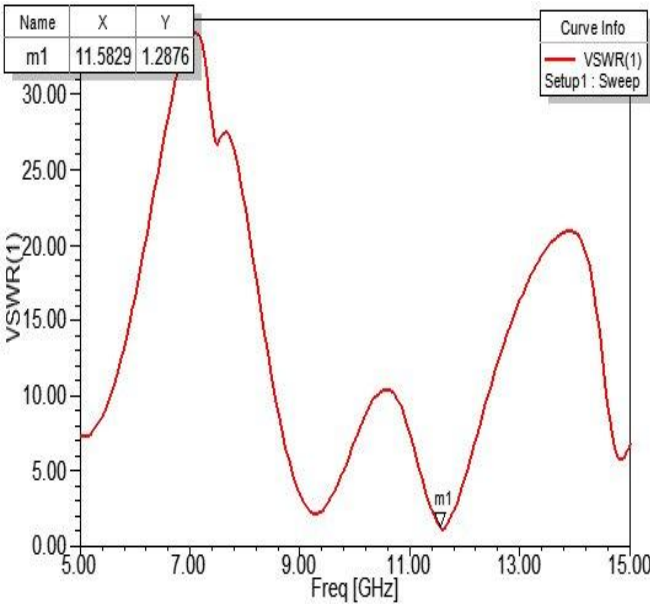

Fig.9 The VSWR plot for the Dual U slot MPA array

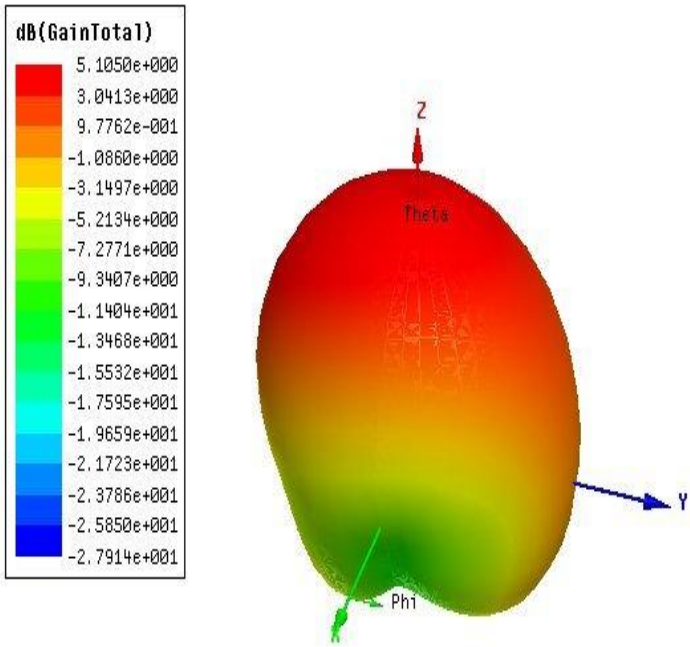

Fig.10 The 3D Polar Plot showing the gain characteristics of Dual U Slot MPA array

4.3 The Proposed Combined H and Dual U Slot Design MPA Array

For the proposed antenna the return loss is calculated firstly. The proposed microstrip antenna array achieved a resonant frequency of 11.03 GHz. The return loss observed was -31.10 dB. The return loss curve with the resonant frequency of 11.03 GHz is shown in the figure11 below.

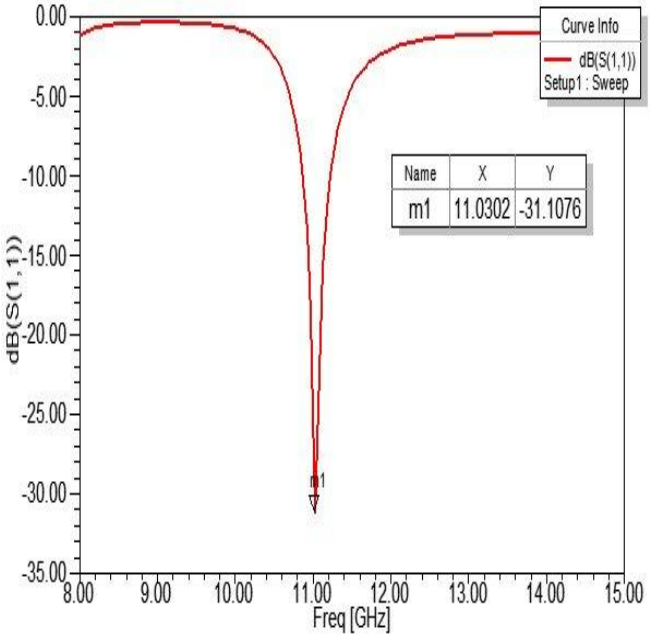

Fig.11 Return Loss versus Frequency Curve for the Proposed MPA Array

In the simulation process after finding the simulated resonant frequency and return loss, the voltage standing wave ratio – VSWR is calculated. The VSWR calculated for the obtained resonant frequency is found out to be 1.0573. For the antenna

to be working efficiently, the VSWR should be less than 2. Since 1.0573 < 2 the VSWR criterion is satisfied. The VSWR plot is shown in the below figure 12.

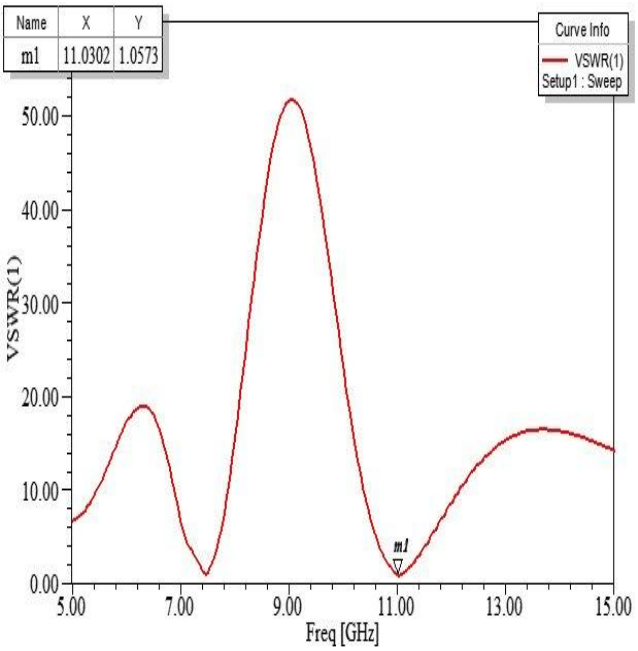

Fig.12 Voltage Standing Wave Ratio curve for the Proposed MPA Array

Subsequently, the 2D radiation patterns are plotted. And the gain characteristics are also given in the figures below. The peak gain value is obtained as 3.34. The 2-dimensional radiation pattern for different values of 'phi' is shown in the below given figure 13. And the 3-Dimensional gain polar plot is given in figure 14.

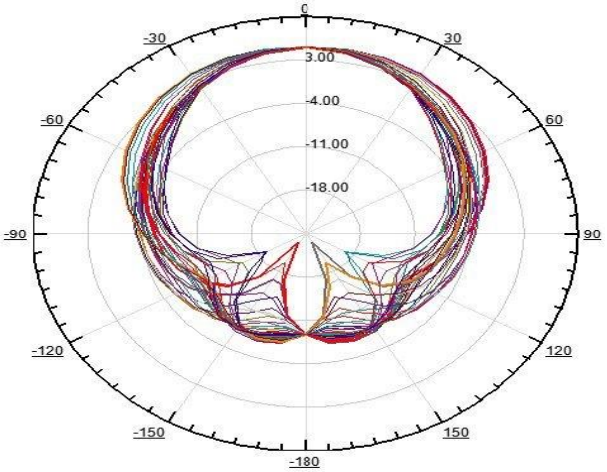

Fig.13 2-Dimensional Radiation Pattern for different values of 'phi' at 11 GHz frequency

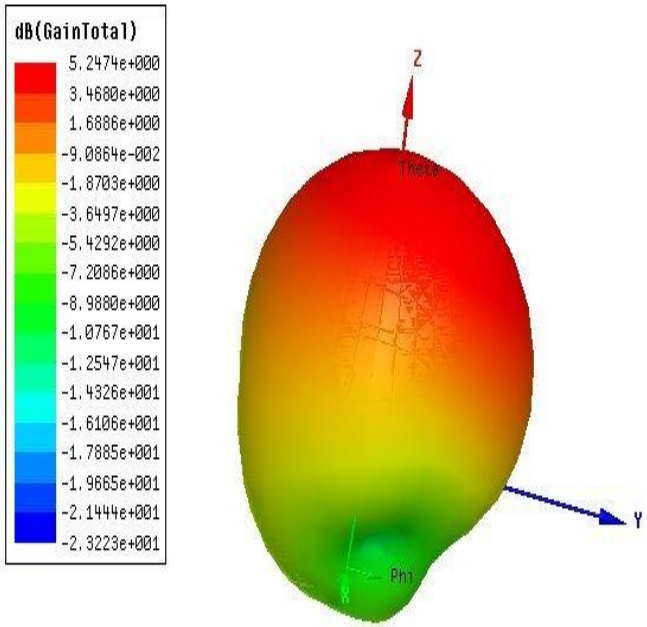

Fig.14 3-Dimensional Gain characteristics plot of the proposed antenna array structure

The comparisons of the above discussed three MPA array structures are done in terms of the return loss plot. Other important antenna parameters such as peak directivity, realized gain and reflection coefficient are also calculated and tabulated below in table 1. The comparisons are shown in below figure 15.

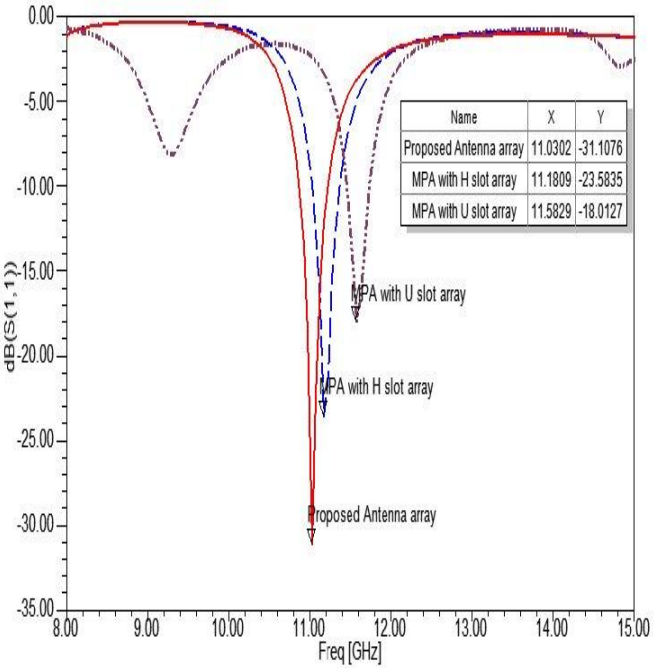

Fig.15 The Compared return loss results for the three MPA array structures considered

The values of some of the important findings from the three antenna array structure are tabulated below in table 1.

Table 1. Important finding from the considered three MPA array structures

S.No	Antenna Parameter	H Slot MPA array	Dual U Slot MPA array	Proposed MPA array
1.	Return loss (in dB)	-23.5835 dB	-18.01 dB	-31.10 dB
2.	VSWR	1.1418	1.2876	1.0573
3.	Gain (in dB)	4.39 dB	5.10 dB	5.25 dB
4.	Reflection Coefficient	0.07	0.13	0.03
5.	Reflected Power (%)	0.4%	1.6%	0.1%

5. CONCLUSIONS

The proposed combined H and Dual U slot design microstrip antenna array with inset feeding is found to resonate at the required frequency of 11.03 GHz (theoretical frequency value is 11 GHz) with a good return loss of -31.10 dB and voltage standing wave ratio less than 2. The proposed antenna also exhibited a gain of 5.25 dB and also the mismatch losses are very minimal. The Proposed MPA when compared with the H slot MPA array and Dual U slot MPA array showed better performance in terms of return loss, VSWR and also the gain and directivity proved to be high with respect to other two microstrip antenna arrays. The X-band covers a frequency band from 8 GHz to 12 GHz. Therefore, this proposed microstrip antenna array can be used extensively in the X-band frequency for satellite applications and radar applications.

6. REFERENCES

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