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Simulation of Rectangular Microstrip Patch Antenna using ANSYS

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***Abstract:** This paper presents the design and simulation of a rectangular microstrip patch antenna with enhanced results. Antennas are playing the most important key role in wireless communication systems and especially microstrip patch antenna is the simplest and best form for mobile communication systems. Therefore, the design of antenna for mobile satellite communication and space to earth communication is described in this proposed work. The working of rectangular micro strip patch antenna is studied and the effect of height of the substrate on antenna performance is analyzed and the results are plotted. It has been noticed that the height of substrate should be neither small nor large. The effect of inserting a slot in the patch is also observed in this paper. Return Loss results are plotted for the designed structure and it is noticed that return loss is almost doubled by inserting a slot. Further two symmetrical slots are inserted in the patch and the respective results are plotted. Insertion of two slots gave multiple operating frequencies to the antenna with a compromise of s11. The simulation of proposed structures of antennas is done using ANSYS HFSS (high-frequency structure simulator) which is commercially used as a finite element method solver for electromagnetic structures. A sphere with human brain characteristics is created and average SAR (specific absorption ratio) is plotted on the head model. The proposed antenna has enhanced return loss of -52dB and VSWR of 1.005 at 2.24GHz. This work also introduces multiple operating frequencies using two slots of same size.*

***Index Terms:** Microstrip, Patch, Slot, Substrate, S11, SAR, VSWR.*

I. INTRODUCTION

In the recent years of development in communication systems, there is a need of light weight, compact and cost effective antennas that are capable of maintaining high performance over a wide spectrum of frequencies. For mobile communications it is very important to maintain small size of antenna. An antenna is a simple transducer which converts electrical signals into electromagnetic waves and vice versa. The reason behind this conversion is that electrical signals cannot be transmitted in free space. Electrical signals need a conductor for transmission whereas electromagnetic waves travel in free space. In some cases, it is not possible to place a conductor for transmission. If antennas wouldn't have been there, it is highly impossible to think about our mobile phones. They would be restricted to simple land line phones without antennas. So, it is obvious that antennas are needed for wireless communication.

The main reason behind the wide range of applications of micro strip patch antenna is its size. The size of micro strip patch antenna is very small which makes it easy to fit in any structure. Also, the construction of micro strip patch antenna is very simple and it's easy to design and fabricate. The structure of microstrip antenna is presented in Fig. 1.

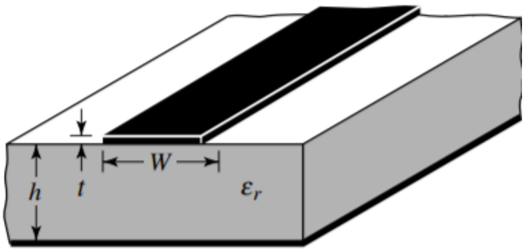

Fig. 1: structure of rectangular micro strip patch antenna

The micro strip patch antenna mainly consists of three layers, namely, ground plane, substrate and patch. Ground and patch are made of conducting material i.e. copper and the substrate is made up of dielectric material which is not a good conductor (insulator).

II. EXISTING WORK

Ander G. Derneryd presented a theoretical investigation of microstrip patch antenna [1]. He also presented that fringing fields play a key role in radiation of antenna. More advanced theory of patch antennas is given by William F. Richards et. al [2], where the input impedance of the patch can be simply varied by varying feed position. A U-shaped slot has been inserted on the patch which enhanced the results of antenna [3]. Current and SAR distribution in human head are studied using an inhomogeneous human head model in [4, 5]. Few techniques to reduce SAR such as insertion of meander lines are introduced in [6, 7, 8]. Meander lines help in reducing the size of the antenna and in also reducing SAR of the antenna [9]. Patch antennas with low SAR are designed and simulated by etching meander lines [10, 11]. Patch antenna with low SAR is proposed in [12, 13]. A comparison of ANSYS HFSS and CST Microwave studio is done and it is concluded that ANSYS converges faster than CST [14]. A complete study of SAR is done by considering 6 layered human head model in [15]

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The dimensions of the antenna are determined by using design equations from [8]. Effective permittivity must be considered because of the fringing fields. Fringing fields travel both in substrate and air. Therefore it is necessary to calculate effective permittivity as operating frequency depends on permittivity. Because of fringing fields, the effective length of the patch inevitably increases. Antenna is designed with predetermined dimensions and simulated using ANSYS. A slot of selective dimensions is inserted at the center of the patch to enhance the results. The simulation results are verified by placing a slot in the patch at various positions with different dimensions. The slot length, width, and position are important parameters in enhancing the results [12].

III. ANTENNA PARAMETES AND DESIGN

A rectangular microstrip patch antenna is designed as shown in Fig. 2 and results are plotted. Later, the effect of, height of substrate, inserting a slot, inserting two slots on patch antenna are observed and results are plotted.

The operating frequency for the antenna is chosen to be 2.24 GHz which comes under S-band. The substrate used is FR4 epoxy with relative permittivity (ϵr) 4.4 F/m. A microstrip feed line is used to feed the patch. Using optimetric analysis, the height of substrate is varied. It is observed that when h is 1.5mm the results are optimum.

Table I: Dimensions of Simulated Antenna

Name of the variable	Length
Lg	60mm
Wg	60mm
Lp	29.5mm
Wp	38mm
H_sub	1.5mm
Lf	19mm
Wf	2mm

The dimensions for the design of antenna are shown in Table 1. The width Wg and length Lg of the ground plane as well as width Wp and length Lp of the patch which are respectively evaluated with the help of design equations. H_sub is the height of the substrate which is chosen to be 1.5mm by performing optimetric analysis to the design in ANSYS HFSS. Lf and Wf are length and width of the feed line respectively. The following equations are used to determine the dimensions of patch. First the width of patch is evaluated by substituting the value of relative permittivity of the substrate.

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_o}}\sqrt{2/(\epsilon\, r+1)} \qquad (1)$$

Due to the fringing fields effective dielectric constant should be calculated. Equation 2 shows the formula to evaluate the effective dielectric constant of the substrate.

Error! Reference source not found. (2)

Due to the fringing fields the effective length of the patch also increases. This can be determined by using equation (3) and (4).

$$\frac{\Delta L}{h} = 0.142\frac{(\epsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \qquad (3)$$

$$L_{eff} = L + 2\Delta L \qquad (4)$$

The actual Length of the patch is given by equation 5.

$$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}}\sqrt{\mu_0\epsilon_o}} - 2\Delta L \qquad (5)$$

Fig. 2 represents the schematic of the rectangular microstrip patch antenna. Fig. 3 represents the same structure designed in ANSYS with the dimensions given in Table I. Fig. 4 shows the antenna design with a slot been inserted at random position with random dimensions. Further, Optimetric analysis is done by placing the slots at different locations with different dimensions and results are plotted. It is found that a slot with length 20mm and width 5mm produce best results when one of its corners is placed at (10, 2.5, 1.5).

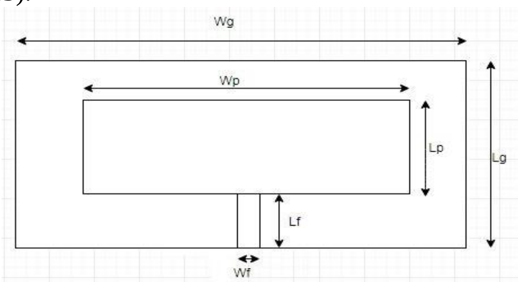

Fig. 2: Schematic of Antenna Design

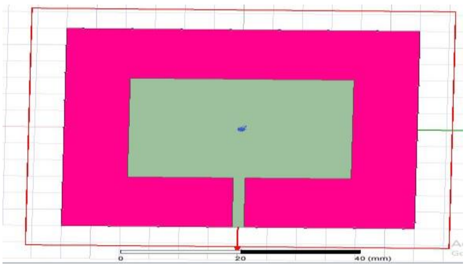

Fig. 3: Design of Antenna in ANSYS HFSS

Fig. 5 shows the design of antenna after inserting two slots. Optimetric analysis is performed on two slots and it is found that the results are best when one slot is placed at (5, -3, 1.5) mm and the other is placed at (5, 3, 1.5) mm each with length of 10mm and width of 5 mm.

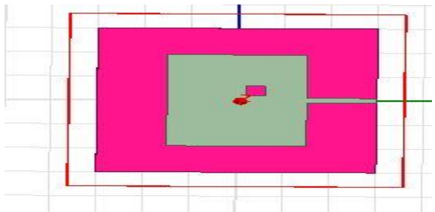

Fig. 4: Antenna with one slot

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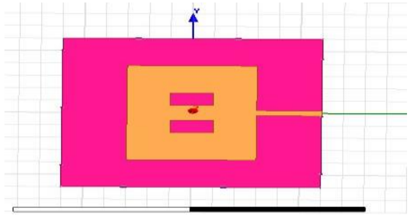

Fig. 5: Design of Antenna with 2 slots

IV. SIMULATION RESULTS

This section describes the results of rectangular microstrip patch antenna with and without slot insertion. SAR observation is also presented. The comparison between the implemented methods also mentioned under this section to see how the return loss and VSWR varies.

A. Results of microstrip patch antenna without slot

(i) S11 Plot

S- Parameter is a very important in determining the performance of the antenna. S11 determines the return loss of the antenna i.e., the amount of input power reflected back is measured by S11. Ideally S11 is expected to be infinitely negative. But practically it never reaches negative infinity and a design with high S11 in negative direction is considered to be the best one.

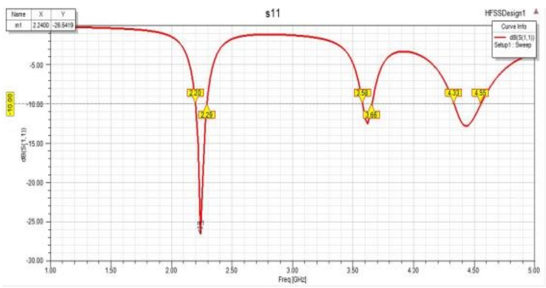

Fig. 6: Plot of S11 for simple microstrip patch antenna

Fig. 6 shows return loss plot of the designed antenna without slot. The minimum acceptable value of S11 is -13dB. For the simulation, it is observed that S11 is -26.54dB at 2.24GHz which is an acceptable value.

(ii) VSWR Plot

VSWR stands for voltage standing wave ratio. This represents the impedance matching and power reflected by antenna. The range of VSWR is 1 to infinity. Ideally VSWR should be close to 1. A structure with VSWR close to 1 is considered to be a good one.

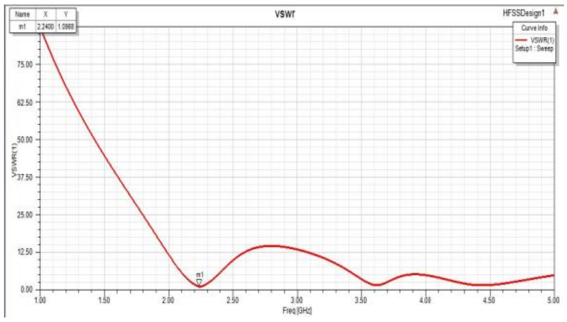

Fig. 7: VSWR plot of simple micro strip patch antenna

Fig. 7 shows the plot of VSWR for the rectangular microstrip patch antenna simulated using ANSYS HFSS. For the proposed antenna VSWR is 1.098 at 2.24 GHz.

(i) SAR Disribution

The value of SAR (Specific Absorption Ratio) is also determined for the designed structure. SAR determines the amount of radio frequencies absorbed by human brain. Maximum SAR is 1.6 W/kg for 1gm averaging mass. Meander line's is a technique which is used to reduce SAR [4]. SAR testing uses models of human head and body that are filled with liquids that simulate the RF absorption characteristics of different human tissue. To test, phone is placed at various common positions next to human body and measurements are taken. SAR is directly dependent on square of the induced electric field which means that a higher electric field within a confined region may result into higher SAR value [5].

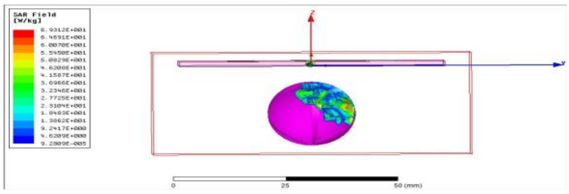

Fig. 8: Average SAR distribution

A sphere is created and the properties of material of brain are assigned to the sphere. The sphere is placed at a distance of 5mm from the centre of antenna structure. Fig. 8 shows average distribution of SAR on a sphere with human brain characteristics which is found to be 1.3W/kg.

B. Results of microstrip patch antenna without slot

(i) S11 Plot

The plot of S11 after inserting a single slot on the patch of antenna is shown in Fig. 9. It can be seen that s11 is almost doubled by inserting a single slot on the patch. At 2.24GHz, the observed return loss Ss11 is -52dB. This high value indicates that maximum input has been transmitted through the antenna and thus it can be said that introduction of a slot reduces the reflections when it is placed correctly.

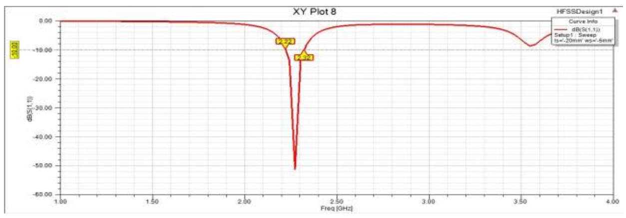

Fig. 9: S11 for length of slot=20mm and width of slot=5mm

The plot of S11 after inserting a single slot on the patch of antenna is shown in Fig. 9. It can be seen that s11 is almost doubled by inserting a single slot on the patch. At 2.24GHz, the observed return loss Ss11 is -52dB. This high value indicates that maximum input has been transmitted through the antenna and thus it can be said that introduction of a slot reduces the reflections when it is placed correctly.

(ii) VSWR Plot

The VSWR plot after inserting the slot in the patch is shown in Fig. 10. It can be seen that at 2.27GHz, the value of VSWR is 1.0055.

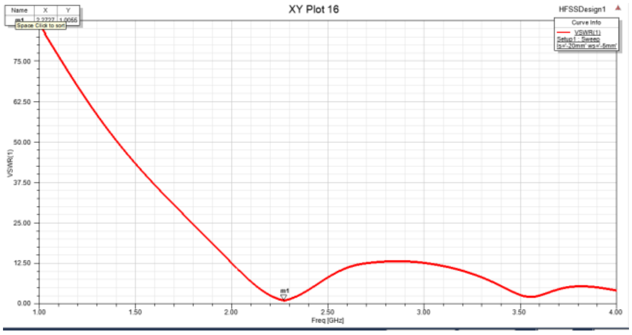

Fig. 10: plot of s11 after inserting a slot

(iii) SAR distribution

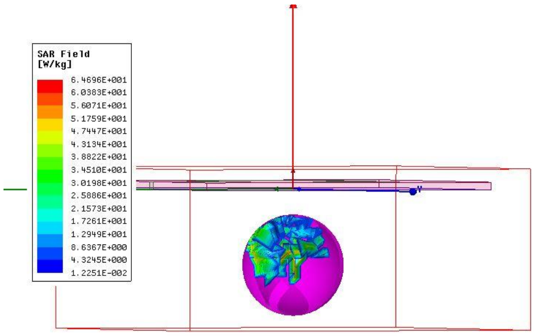

Fig. 11: plot of SAR

Fig. 11 represents the SAR plot on sphere with human head characteristics. The value of SAR is absorbed to be 1.225 after insertion of slot.

C. Results of patch antenna with two slots

(i) S11 Plot

Fig. 12 shows the s11 plot after inserting two slots on the patch. the length and width of two slots are 10mm and 5mm respectively which are placed with a distance of 6mm from each other. From Fig. 12, it can be seen that the antenna is operating at multiple frequencies because of insertion of two slots. Apart from 2.2GHz it is also operating well at 3.4GHz and 4.38GHz.

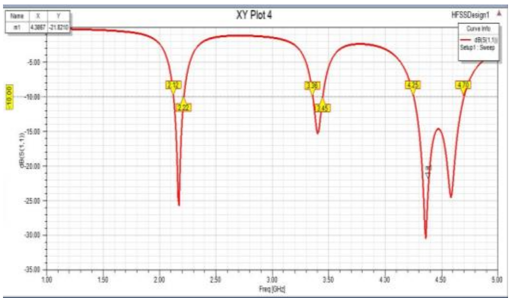

Fig. 12: S11 plot with two slots in patch Antenna

(ii) VSWR Plot

Fig. 13 shows the VSWR plot after inserting two slots in the patch. the values of VSWR are 1.57, 1.44 and 1.11 at 2.2GHz, 3.4GHz and 4.38GHz.

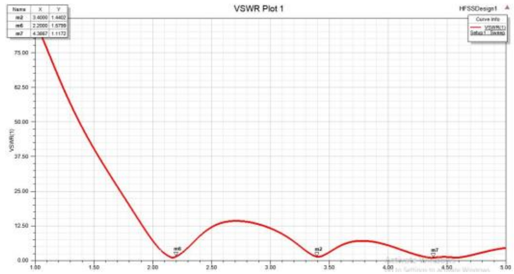

Fig. 13: VSWR plot with two slots in patch Antenna

(iii) SAR distribution

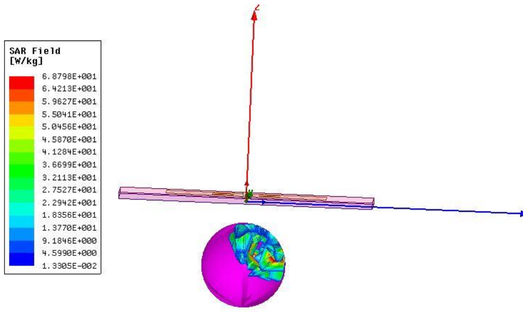

Fig. 14: SAR plot after inserting two slots

Fig. 14 represents the plot of SAR on sphere with human head characteristics after inserting two slots in patch antenna. The value of SAR is found to be 1.33 w/kg.

Table II gives a comparison among the different techniques implemented to enhance the results of antenna. The rectangular microstrip patch antenna designed in the first stage operates at 2.24GHz with a return loss of -26.54dB and VSWR of 1.09. Insertion of slot has almost doubled the return loss and the value of VSWR has been further reduced to 1.005. Insertion of two slots gave multiple operating frequencies to the antenna. Therefore this can be used for various applications. The different operating frequencies are 2.2GHz, 3.4GHz and 4.38GHz with return loss of -26dB, -15dB and -30.5dB respectively. VSWR is 1.11 at 2.2GHz.

Table II: comparison of results for different techniques

parameter	patch antenna	Single slot	Two slots
Operating frequency	Operates at 2.24GHz	Operates at 2.24GHz	Operates at multiple frequencies
S11	-26.54dB at 2.24GHz	-52dB at 2.24GHz	-26.1dB at 2.16GHz -14.9dB at 3.41GHz -35.2dB at 4.36GHz
VSWR	1.09 at 2.24GHz	1.005 at 2.27GHz	1.17 at 2.16GHz 1.44 at 3.41GHz 1.04 at 4.36GHz

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V. CONCLUSION

A rectangular microstrip patch antenna is simulated using ANSYS HFSS in S band for applications such as airport surveillance radar for air traffic control, weather radar, mobile satellite communication and space to earth communication. An optimized value for thickness of substrate is obtained by using optimetric analysis and 1.5mm is considered to be the best fit value for thickness of substrate to attain better return loss and VSWR. From this work it is observed that insertion of a slot on the patch enhanced the return loss. Multiple operating frequencies for the antenna have been observed by inserting two slots on the patch. The value of SAR has been evaluated for all the structures and it is observed that it is within the required range for all the structures. The results can be further enhanced in future by introducing meander lines for the proposed patch antenna.

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