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Designing and Performance Evaluation of S and C Slot Rectangular MicrostripPatch Array Antenna

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Abstract: This paper presents the design of micro-strip patch antenna using high-frequency structure simulator (HFSS 12). The two different configurations S-slot & C-slot rectangular patches are designed. The performance of two antennas is analyzed in terms of bandwidth, return loss and gain. The material used for the substrate is FR4 having the dielectric constant 4.4. This material is easily available & has low cost. The return loss of S slot rectangular patch is -36.53db & gain is 5.3009 db whereas the return loss for C slot is -34.99 db and gain is 4.8762 db.

Keywords: Antenna, Directivity, Gain, HFSS, Radiation Pattern, SAR.

I. INTRODUCTION

An antenna is a device used to transform an RF signal, traveling on a conductor [1], into an electromagnetic guided wave in free space, and vice versa (i.e., in either transmitting or receiving mode of operation). Antennas are frequency-dependent devices. Each antenna is designed for a certain frequency band, and it rejects signals beyond the operating band [5]. For that reason, antennas can be considered bandpass filters and transducers. In addition, an antenna in advanced wireless systems is usually required to optimize the radiation energy in some directions and suppress it in others. .Nowadays, these devices constitute an essential part of wireless communication systems [8].Basic antenna classification depends on design, mode of operations and their applications. The isotropic point source radiator which radiates the same intensity of the electromagnetic signal in all directions, However, do not exist but is used to measure other antennas' gains.

Microstrip patch antennas have many unique and attractive features, like lightweight [3] [4] [5] [6], low profile, easy fabrication, compact and conformability to mounting structure [2]. Due to low bandwidth, the applications of microstrip patch design are very less [7].

II. AIM AND OBJECTIVE

As we have come to know that the Microstrip Antenna find application in the mobile communication, spacecraft, aircraft etc. due to their low profile, low weight, assessment with printed circuit technology, our aim in this thesis is to design Rectangular Microstrip patch Antenna operating in 1-2 GHz frequency range which finds application in Military, Global Positioning System (GPS), Telecommunication, Digital Audio Broadcasting (DAB) etc. It lies in the IEEE L Band. The tool used for the antenna design is HFSS 12. The values of Return Loss and Gain obtained in our designed antenna are quite good.

III. INTRODUCTION TO ANTENNA DESIGN IN HFSS

Ansoft HFSS 12(High-Frequency Structure Simulator) is a high-performance full-wave electromagnetic (EM) field simulator used to solve any arbitrary 3-D geometry. It provides a quick and accurate solution to the 3-D EM problems integrating simulation & Visualization. It can be used to calculate parameters such as S-parameter, resonant frequency and fields. It employs finite Element Method(FEM), adaptive meshing & graphics to solve the problem. The various features of HFSS12 are [9]:

i. Most accurate representation of curved & conformal structures.
ii. It reduces solution time and RAM usage.
iii. The parametric operations performed are:-
   a. Boolean operations
   b. Moving Faces
   c. Arrange objects
   d. Duplicate objects.
iv. GUI (Graphical User Interface) options for large models enable faster model interaction.
v. It enables full wave design of an antenna in the operating environment.

Now we will study the design of Rectangular Patch Microstrip Antenna in HFSS12.

The Microstrip antenna consists of mainly four parts- Substrate, Ground, Patch & Feedline. I have designed the four configurations of microstrip antenna:

1. Simple Rectangular Patch Microstrip Antenna
2. Rectangular Microstrip Patch Antenna With C Slot
3. Rectangular Microstrip Patch Antenna With S-Slot
4. Dual stacked Rectangular Microstrip Patch Antenna.

These antennas are designed and simulated using HFSS 12 Software. The various design steps are:

1. First of all, the substrate is designed using the command create a box. The dimensions of the box are defined & also it's position in the coordinate system is defined. The other design configurations are the selection of the material of the substrate. The relative permittivity of the substrate affects the properties of the antenna so the substrate material is selected according to the relative permittivity. In our design, we have used FR4 as the substrate material having the relative permittivity 1.4.

2. Now the rectangular patch is designed using the command draw line. According to the size of the patch, the dimensions of the four lines of the rectangle are defined. After the rectangular patch is drawn its position in the coordinate system is defined.

3. After this, the ground is designed using the command draw rectangle. The dimensions and position of the substrate are same as that of the ground.

4. The next important step in the design of the antenna is drawing the feedline. The feedline used in our design is a cylindrical cable having 50-ohm input impedance. For designing the feedline following steps are performed:-

First of all, a slot is made in the ground. For this, a circle is drawn. It's radius & position on the ground are defined. The position of the slot affects the radiation pattern of the antenna. After designing the slot it is subtracted from the ground. The command used is subtracted from the Boolean part of the modeler in HFSS.

I. Co-axial line feeding is used in our design, for this a cable is drawn using the command draw cylinder. It's radius and position are defined same as that of the circle drawn in the previous step for the slot and height of the cable is made same as the height of the substrate. The other design considerations are the selection of material. We have used Teflon as the material of the cable.

II. After the cable is drawn the conducting pin is drawn. It is also drawn using the command draw cylinder. It's radius is made less than the radius of the cable but it's position and the height is same as that of the cable. The material used for the conducting pin is 'pec'. The conducting pin is made of the cable as well as inside the substrate so that the radiations can reach the patch. The .design steps are the same except that the height is now made positive.

III. Now a port is made at the end of the cable named as the wave port. It is designed using the command draw circle. It's radius and position are same as that of the lower end of the cable. After it is designed a perfect impedance of 50 ohms is assigned to it. The steps involved in assigning the impedance are GO TO HFSS → Excitation → Assign → Waveport → Renormalize → Perfect Impedance → 50 ohm → Finish

5. To study the characteristics of the antenna Environment is created around it using the command draw box. It's size and position is same as that of the substrate except for the height. The height of environment is made larger than the substrate and above the antenna.

6. After Ground, Patch and Environment are drawn the next step is to assign excitations & boundaries to it. Perfect E field

is assigned to Ground and Patch. The commands used are HFSS → Radiation →I*nsert far field* →Perfect E. For Ground infinite ground is selected.

7. Radiations are assigned to the Environment Faces. For this first of all the four faces of the Environment are selected using the select faces option and then radiation is assigned to the faces by HFSS →Boundaries → Assign →Radiation.

8. The designing of the antenna is followed by the Analysis. The steps involved in the analysis are:-

i. HFSS → Analysis Set Up → Add Solution Set Up → Set Solution frequency.
ii. HFSS → Analysis Set Up → Add Sweep Type → Add Count → OK.
iii. After this Analyze All command is given to check whether there is an error Or the design is OK.
iv. If after analysis there is no error then the antenna design is simulated to get the results.
v.

IV. DESIGN OF SIMPLE RECTANGULAR PATCH

The Simple Rectangular Patch Antenna Designed is shown below:-

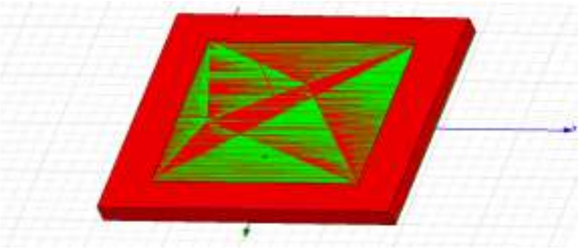

Fig.1 Simple Rectangular Patch

The design parameters are: Substrate Material: FR4, Dielectric Constant: 4.4, Size of Substrate: 100X95X8mm, Size of Patch: 72X67 mm

V. DESIGN OF RECTANGULAR MICROSTRIP ANTENNA WITH S SLOT

The designing steps of this antenna are same as that of the simple rectangular antenna except that an S –slot is made in the rectangular patch to increase the directivity and gain of the antenna. The S-Slot is drawn using the command draw line. Coordinates of the different end points are defined to draw it. It is then placed on the patch and subtracted from it. The design parameters are: Substrate Material: FR4, Dielectric Constant: 4.4, Size of Substrate: 120X115X8mm, Size of Patch: 79X80.8 mm

The Rectangular patch with S- Slot is as shown below:-

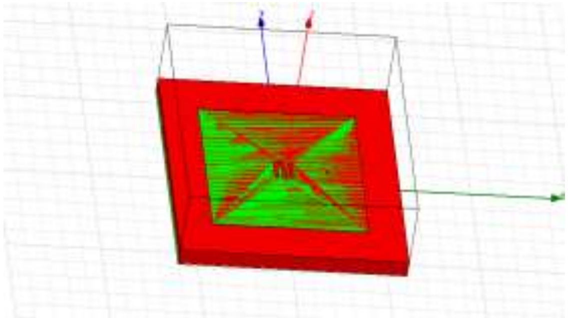

Fig.2 Rectangular Patch Antenna With S Slot.

VI. DESIGN OF RECTANGULAR MICROSTRIP ANTENNA WITH C – SLOT

The design of Rectangular Microstrip Antenna with c- slot is shown below:

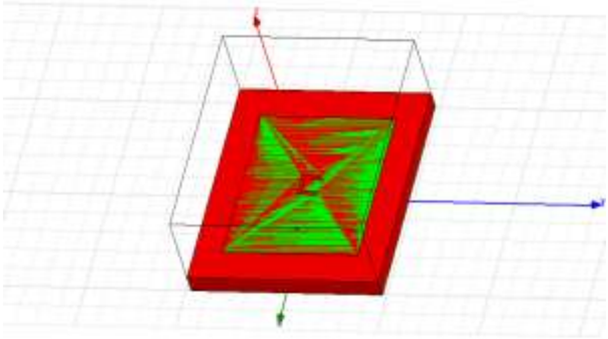

Fig. 3 Rectangular Patch Antenna With C - Slot.

The design parameters are: Substrate Material: FR4, Dielectric Constant: 4.4, Size of Substrate: 100X95X8mm, Size of Patch: 72X67 mm

VII. DESIGN OF DUALSTACKED RECTANGULAR PATCH ANTENNA

In the design of this antenna, a second layer of the patch of the same size and the same material is placed over the previous patch layer to increase the gain of the antenna. The design parameters are: Substrate material: FR4, Dielectric Constant: 4.4, Size of Substrate: 120X95X8 mm, Size of Patch: 52x67 mm

The design of Dual stacked Rectangular Patch Antenna is shown below:

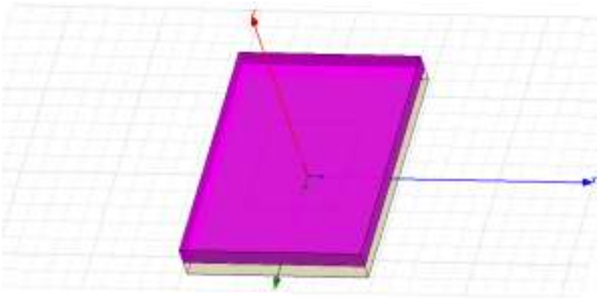

Fig.4 Dual stacked Rectangular Patch Antenna

VIII. SIMULATION AND RESULTS

Simulation of Simple Rectangular Patch Microstrip Antenna:

It is simulated using the command HFSS → Results → Create Modal Solution Data Report → Rectangular Report → S-Parameter → New Report to generate the Return Loss.The Return Loss for Simple Rectangular Patch antenna is shown below:

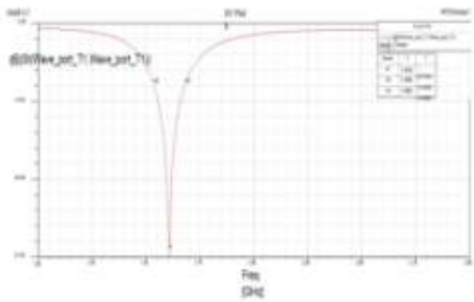

Fig. 5 Return Loss Vs Freq. Graph of Simple Rectangular Patch Antenna.

The graph of current distribution is:

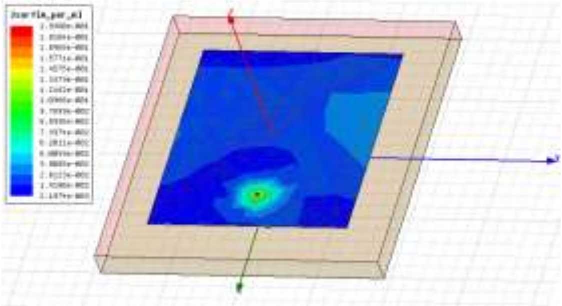

Fig. 6 Graph of Current Distribution in rectangular Patch Antenna

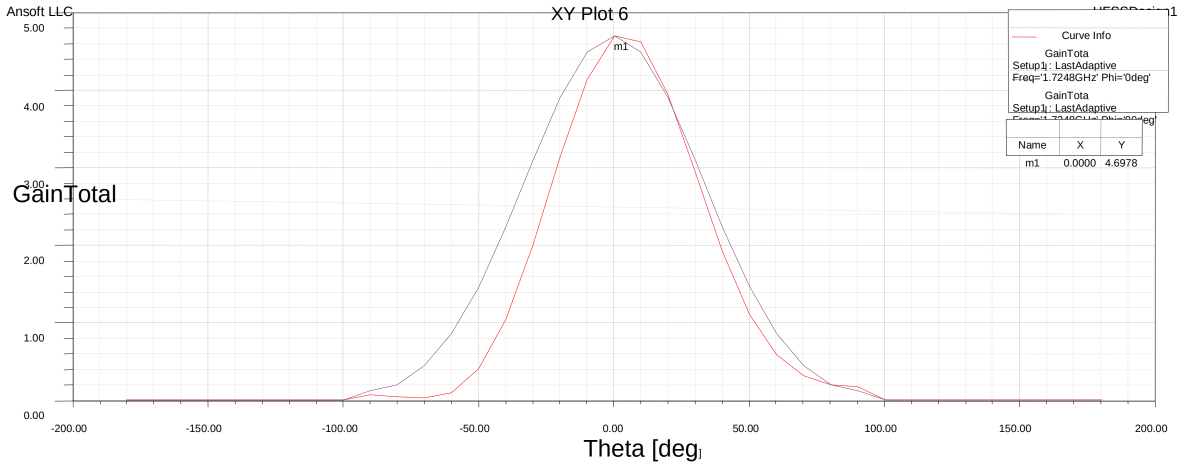

Fig. 7 Gains vs. Theta of Simple Rectangular Patch

The graph of gain is generated by HFSS → Result → Create Far Field → Radiation Pattern → Families → GainThe 3-D Polar Plot is drawn by HFSS → Result → Create Far Field → 3-D Polar Plot

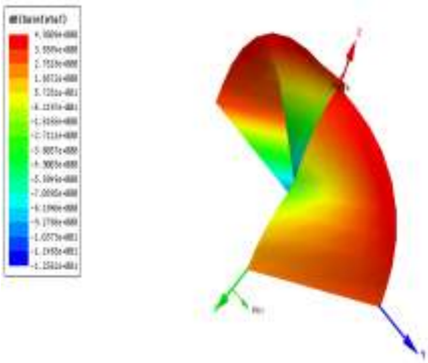

Fig. 8 3-D Polar Plot of Total Gain Db

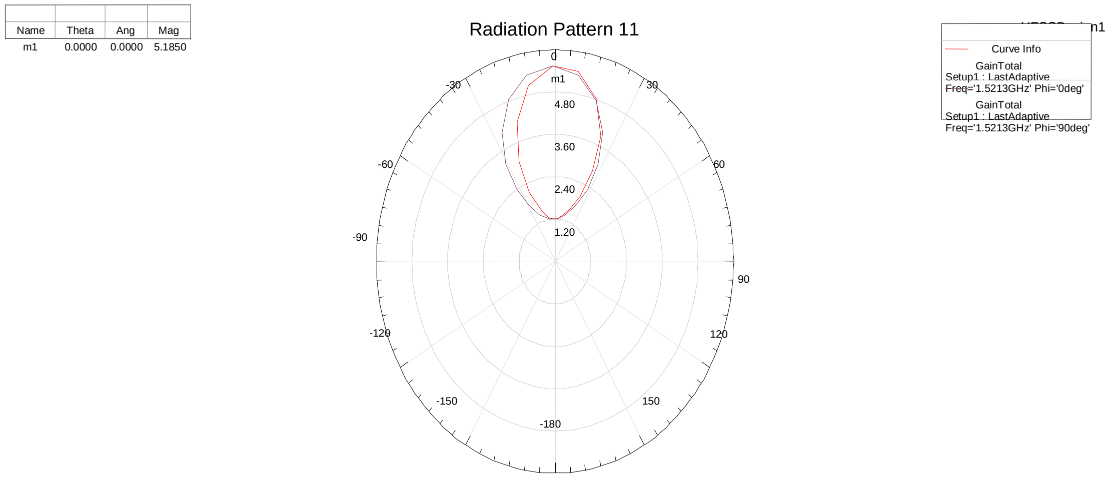

Fig 9 Radiation Pattern of Simple Rectangular Patch.

Simulation of Rectangular Patch Microstrip Antenna With S-Slot:

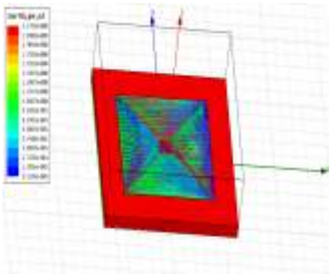

Fig. 10 Graph of Current Distribution in rectangular Patch Antenna with S – Slot

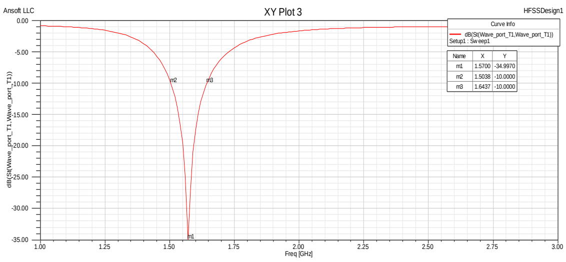

Fig.11 Return Loss Vs Freq. Graph of Rectangular Patch Antenna With S - Slot

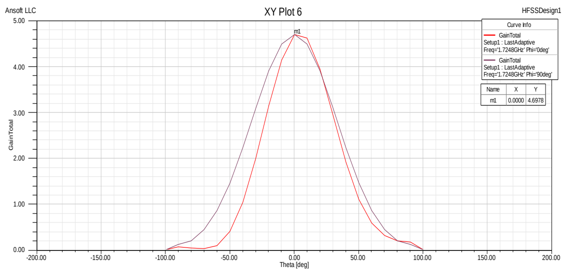

Fig. 12 Gain Vs. Theta of Rectangular Patch Antenna With S - Slot

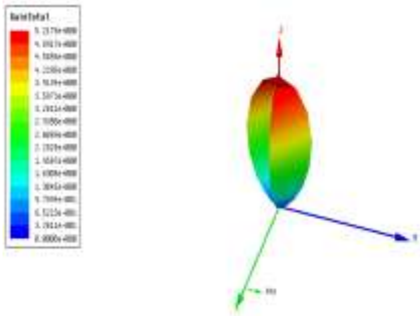

Fig. 13-D Polar Plot of Total Gain dB

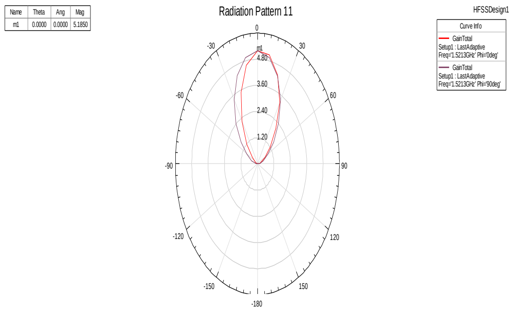

Fig 14 Radiation Pattern of Rectangular Patch Antenna With S – Slot

Simulation of Rectangular Patch Microstrip Antenna With C-Slot:

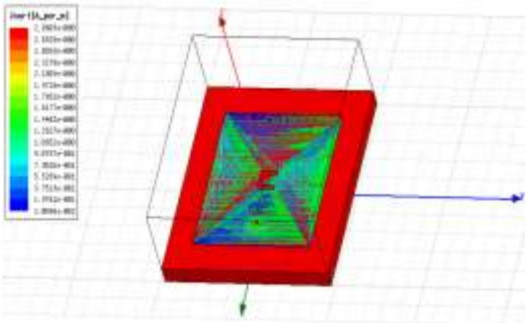

Fig. 15 Graph of Current Distribution in rectangular Patch Antenna with C - Slot

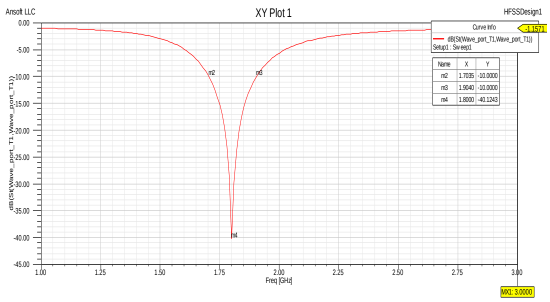

Fig. 16 Return Loss Vs Freq. Graph of Rectangular Patch Antenna With C – Slot

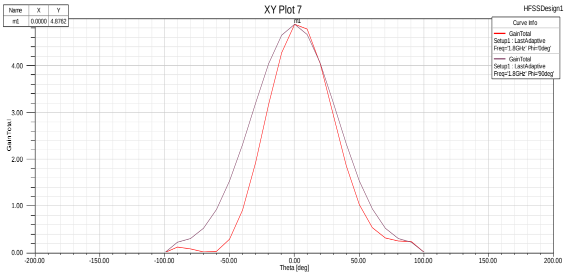

Fig. 17 Gains vs. Theta of Rectangular Patch Antenna With C - Slot

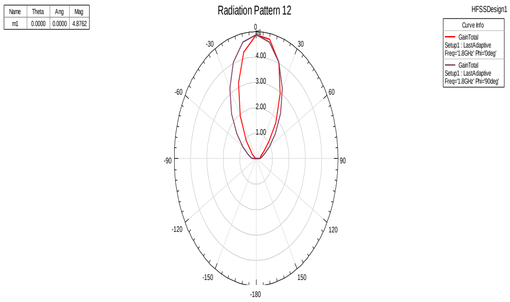

Fig 18 Radiation Pattern of Rectangular Patch Antenna With C – Slot

Simulation of Dual stacked Rectangular Patch Microstrip Antenna:

The following figure shows the graph of the return loss of Dual stacked Rectangular Patch. The results obtained for this patch are the best.

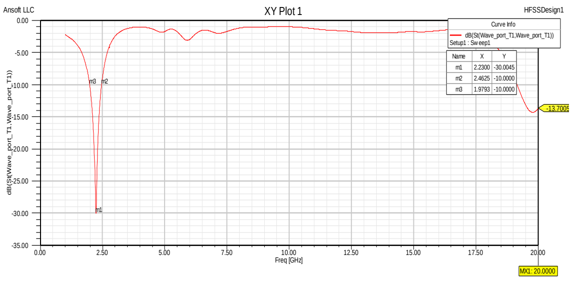

Fig. 19 Return Loss Vs Freq. Graph of Dual stacked Rectangular Patch Antenna.

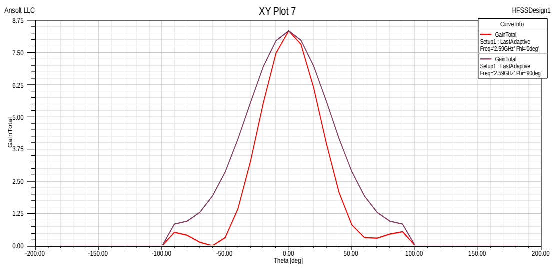

Fig. 20 Gain Vs. Theta of Dual stacked Rectangular Patch Antenna

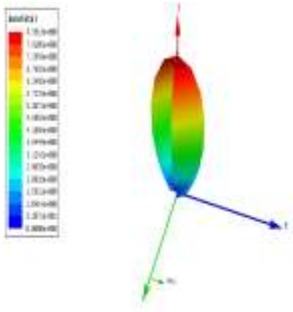

Fig. 21 3-D Polar Plot of Total Gain dB

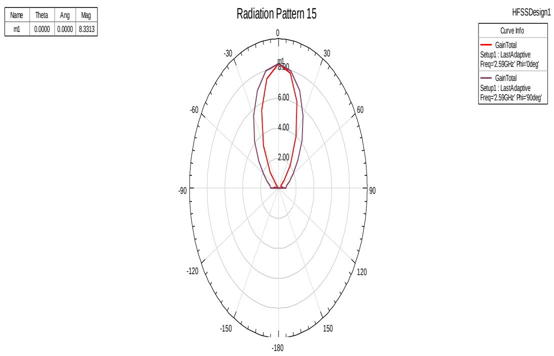

Fig 22 Radiation Pattern of Dual stacked Rectangular Patch

Table 1.1

Comparison of different parameters of different patch antenna configurations:

SR. NO.	Configuration	FH(GHz)	FL (GHz)	Resonant Frequency(GHz)	Bandwidth	% Bandwidth	Return loss (dB)	Gain(dB)
1.	Simple Rectangle	1.7059	1.9064	1.8023	0.2005	11.124	-33.3	4.6161
2.	C slot	1.5038	1.7437	1.57	0.2399	15.2	-34.9970	4.8762
3.	S Slot	1.5380	1.6802	1.61	0.1422	8.8	-36.5348	5.3009
4.	Multistacked	1.9793	2.4625	2.23	0.4832	21.6	-30.045	8.3313

CONCLUSION

In this dissertation work, four configurations of rectangular patch Microstrip antenna are designed using the software HFSS 12 and simulated. The various antenna parameters studied are return loss, Gain, and Bandwidth. After designing and simulation we can say that there are many aspects that affect the performance of the antenna such as Dimensions, selection of the substrate, feed technique, and shape of the patch, multistacking. The comparison of various antenna parameters for all the four configurations is shown in table 1.1. There is an improvement in the antenna parameters with the slots in the patch. The C slot patch shows better results than the S slot Patch Antenna. The best results are shown by the dual stacked rectangular patch antenna. With the multistacking gain as well as the bandwidth of the antenna are doubled.

FUTURE SCOPE

The manual calculation of all parameters of the antenna is complex. By the use of the HFSS12, this can be easy to calculate it. The effect of the Changes in the different configurations on radiation pattern, gain, return loss and bandwidth can be easily analyzed

by the use of HFSS12. As mentioned in results by changes in the patch configuration, parameter of the Microstrip antenna is changed, this will help designer to determine the antenna performance and make a necessary adjustment before fabrication.
A further study can look into the design of a microstrip patch antenna array operating at a different frequency. This will further improve the antenna with very directive characteristics or very high gains to meet the demands for long distance communication as well as providing a fixed beam of specified shape (shape beam) or a beam that scans in response to system stimulus.

As the antenna designed operates in the IEEE L-Band which is used in various applications such as Military, Global positioning System, digital audio Broadcasting etc.

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