Design and Improvement of Microstrip Patch Antenna parameters Using DGS For Wifi Applications

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ABSTRACT

this research paper deals with the design and development of the microstrip patch antenna with frequency A 2.4MHz in Wi-Fi applications. We designed and analyzed this type of antenna, improving both the bandwidth, gain, directivity, reducing return losses and VSWR, and introducing the Defected Ground Structure (DGS) through the work of four scenarios, the first is individual antenna design without defective in the ground and the second antenna is an array without defective in the ground. The third was an individual antenna with defective in the ground and the fourth antenna was an array with defective in the ground. They compare the four designs and highlight the best among them, taking into account the small size of the microstrip patch antenna.

Keyword- Microstrip Patch Antenna, Bandwidth, Gain, Directivity, VSWR, Return Loss, Defected Ground Structure (DGS), CST studio.

1. INTRODUCTION

Microstrip patch antennas are more popularly used nowadays due to their various advantages such as being lightweight, less volume, compatibility with integrated circuits, easy to install on the rigid surface, and low cost[1]. Microstrip patch antennas are designed to operate in dual-band and multi-band applications either dual or circular polarization. These antennas are used in different handheld communication devices. However, microstrip patch antennas are having narrow bandwidth and bandwidth enhancement is necessary for most of the practical applications, so for increasing the bandwidth different approaches have been utilized[2]. Defected Ground Structure is one of them. In addition, most of the applications which use microstrip antenna in communication systems like mobile handheld communicating devices require a smaller antenna size. Different advanced tools for the design of very compact microstrip patch antennas have been introduced over the last few years. The meaning of DGS is the in-ground plane of patch antenna some defected shape is introduced and depending on the different dimensions, shape, and size of the defect the shielded current distribution will get disturbed[3][4]. Input impedance and the current flow of the antenna will get affected due to disturbance at the shielded current distribution. It can also control the excitation and electromagnetic waves which are propagate through the substrate layer. The main objective of this project is to design and analyze microstrip rectangular patch antenna by adding in many patch (2xN) antennas in the array for Wi-fi application at 2.4GHz[5]. The design's performance will be more focused on return loss, Voltage

Standing Wave Ratio (VSWR), bandwidth, directivity, and gain and will be simulated and tested by CST Studio Suite software. in this design, we Simulated rectangular microstrip patch antenna arrays for Wi-fi applications at 2.4GHz also evaluate the performance between the single patch and patch array microstrip antenna. To develop the antenna that provides high gain, directivity, wide bandwidth, and higher efficiency by inserting ground slots. To look at the characteristics of the patch antenna, return loss, Voltage Standing Wave Ratio (VSWR), bandwidth, directivity, and gain.

2. ANTENNA DESIGN

In this section, We have designed a single and array rectangular microstrip patch antenna with and without slots on the ground by using FR-4 dielectric substrate. The dielectric constant is 4.3, substrate height is 1.6 mm. The antenna was designed on a substrate of dimension 29 mm × 38 mm. This antenna structure is going to be made in CST studio. The simulation of the antenna is carried out using CST studio software. As we have designed four rectangular patch antennas with different scenarios.

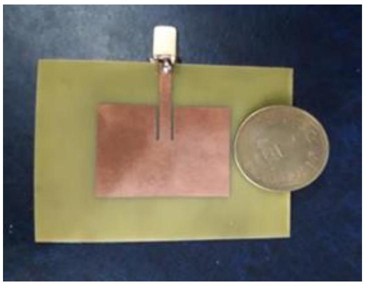


Fig. 1. shows the type of antenna that is going to be designed

Used FR-4 material with relative dielectric constant (εr) of 4.4 for the substrate and annealed copper (Cu) are used for the patch, ground plane and microstrip feeding line of each antenna.

The operating frequency (fr) is considered as 2.4 GHz and the height of the dielectric substrate (h) is considered . Patch width (W), effective dielectric constant (εreff) patch length extension (ΔL), effective patch length (Leff), patch length (L), ground plane width (Wg), ground plane length (Lg), substrate width (Ws) and substrate length (Ls) of the antennas are calculated for of (fr) and (εr) as in .

A. Calculation of Patch Width (W):

$$w = \frac{1}{2fr\sqrt{\mu 0 \epsilon 0}} \sqrt{\frac{2}{\epsilon r + 1}}$$

B. Calculation of Effective Dielectric Constant (ε_{reff}):

$$\varepsilon_{reff} = \frac{\varepsilon_{reff} + 1}{2} + \frac{\varepsilon_{reff} - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2}$$

C. Calculation of Patch Length Extension (ΔL):

$$\Delta L = 0.412\, h \frac{(\varepsilon reff + 0.3)(\frac{w}{h} + 0.264)}{(\varepsilon reff - 0.258)(\frac{w}{h} + 0.8)}$$

D. Calculation of Effective Patch Length $(Leff)$:

$$Leff = \frac{c}{2fr\sqrt{\varepsilon r}} - 2\Delta L$$

E. Calculation of Patch Length (L):

$$L = Leff - 2\Delta L$$

F. Calculation of Ground Dimensions (Lg, Wg):

$$Lg = 6h + L$$
$$Wg = 6h + W$$

In the following table are the values of the variables and dimensions that were used in the Microstip Patch Antenna design in the four scenarios:

Table 1: Values used create a patch antenna

Parameter	Value(mm)	Length
L	29	Length
W	38	Length
Lg	58	Length
Wg	76	Length
d	11	Length
Fi	14.5795	Length
Ws	1	Length
Wf	3.135	Length
h	1.6	Length
t	0.1	Length

3. METHODOLOGY

Using the obtained data shown in the previous table, we designed four rectangular microstrip antenna scenarios with the same specifications as the single rectangular antenna and introduced defective ground technology to improve performance and raise antenna efficiency while maintaining the small size and usability of this antenna. We compared the types designed with the same dimensions with the difference in the presence of defective technology in the grond and note the difference between them.

1. **Scenario 1:**

In this scenario we designed a single patch antenna as shown in Figure 2.

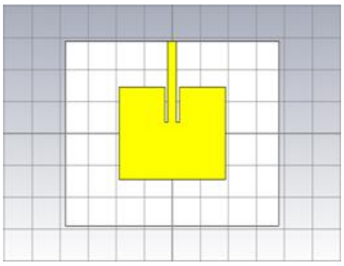


Fig.2. Signal patch antenna.

2. **Scenario 2:**

In this section we designed a two element patch antenna array as shown in Figure .3

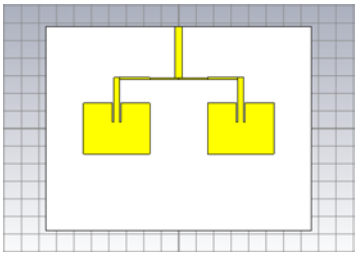


Fig. 3. 2x1 element patch antenna array.

3. **Scenario 3:**

In this scenario, we designed a single rectangular patch antenna with the same physical dimensions used in scenario 1 but with inserting ground slots as shown in Figure 4.

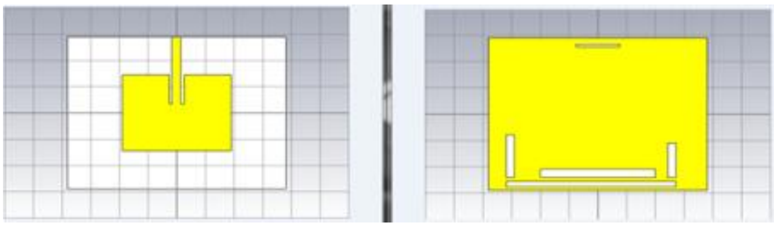


Fig. 4. Single Microstrip patch antenna with slots in ground plane.

4. **Scenario 4:**

In this scenario we used the same design in scenario 2 (2x1 elemeny patch antenna array), but by using defective technology in the grond as shown in Figure 5.

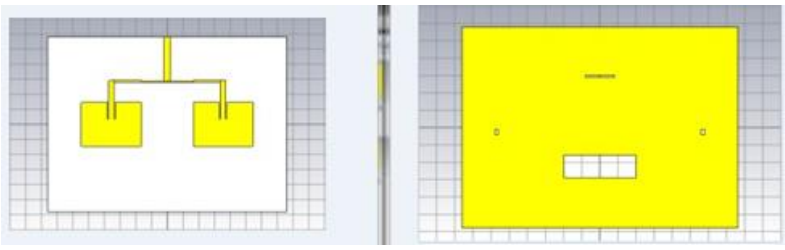


Fig. 5. Two element microstrip patch antenna array using DGS.

4. RESULT AND DISCUSSION

All the results presented in this paper are produced by the simulation software called Computer Simulation Technology Studio Suite (CST Studio Suite). It has powerful drawing capabilities to imply the antenna design. In this paper, the various results such as radiation patterns, 3-D Gain plots, return loss and VSWR plots are discussed. All the simulations were made with the frequency domain solver in CST[6].

I. Return loss

It is a parameter that is used to measure the power reflected by the antenna due to the mismatch of the antenna. Let us consider an example if the return loss is 0dB there is nothing to radiate by the antenna because the power provided to the antenna is completely reflected by the antenna or this means that the power input is equal to the power reflected.

A. Scenario 1 Shows the result of Return loss of single patch antenna without slotted:

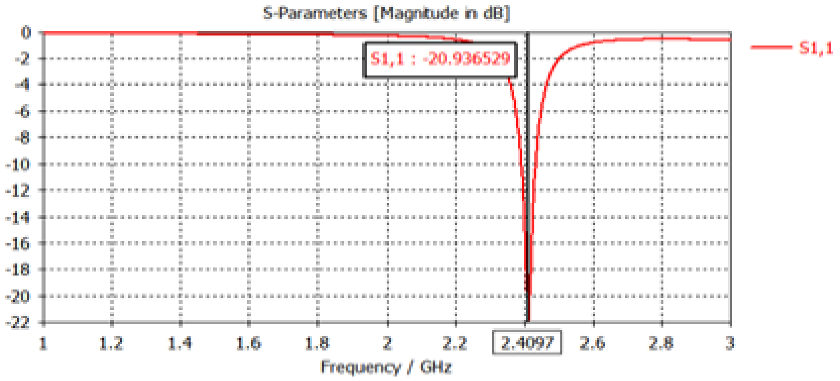


Fig. 6. Return loss of single patch antenna without slotted at 2.4 GHz.

B. Scenario 2 Shows the result of Return loss of two element patch antenna array without slotted:

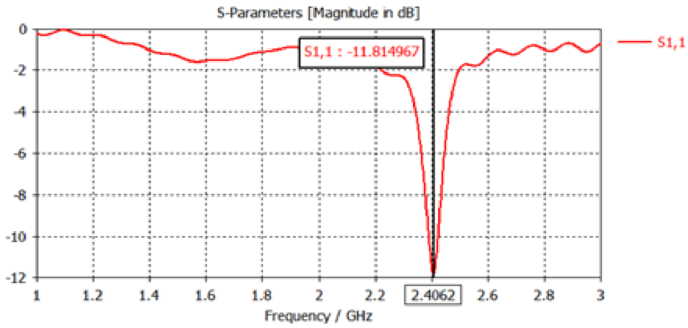


Fig. 7. Return loss of two element patch antenna array without slotted at 2.4 GHz.

C. Scenario 3 Return loss of single patch antenna with slotted:

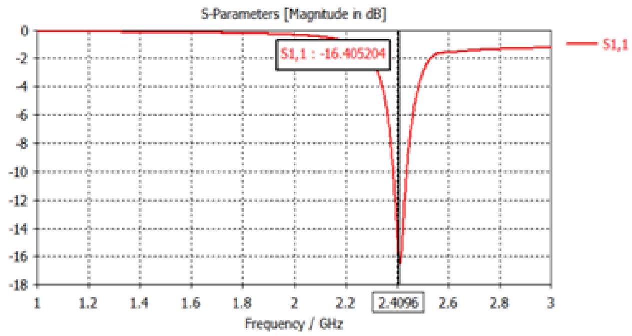


Fig. 8. Return loss of single patch antenna with slotted at 2.4GHz.

D. Scenario 4 Shows the result of Return loss of two element patch antenna array with slotted:

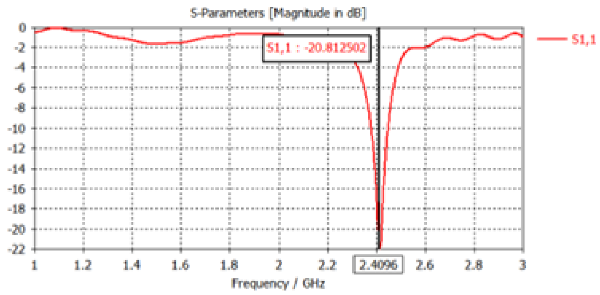


Fig. 9. Return loss of patch antenna array with slotted at 2.4 GHz.

In this part, we presented the results of return losses and compared the results of the four designs ،and noted the discrepancy in the results concerning return losses. There are reasonable rates for return losses because the antenna variables are related to each other.

II. Bandwidth

The bandwidth is the range of frequencies over which the antenna can operate correctly.

A. Scenario 1 and Scenario 2 Show the results of bandwidth for a single and 2x1 element patch antenna without slotted:

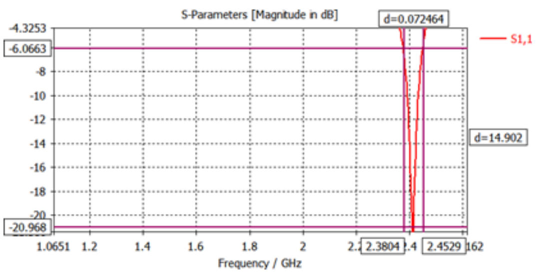


Fig. 10. Bandwidth of single patch antenna.

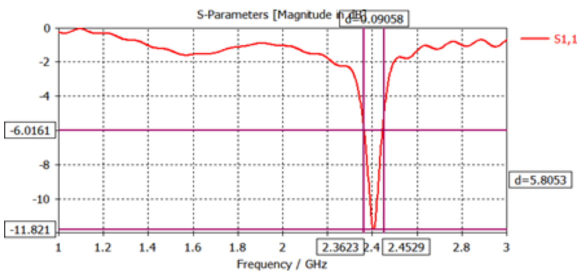
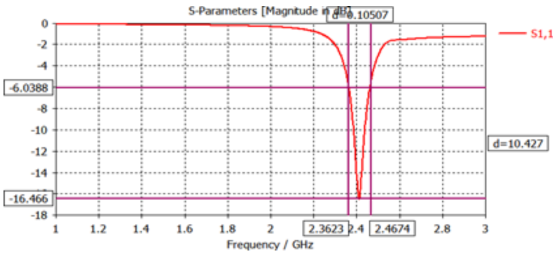


Fig.11. Bandwidth of two element patch antenna array.

B. Scenario 3 and Scenario 4 illustrates the bandwidth for a single and 2x1 element patch antenna with slotted. So from the figure 12 and figure 13 below shows given results:



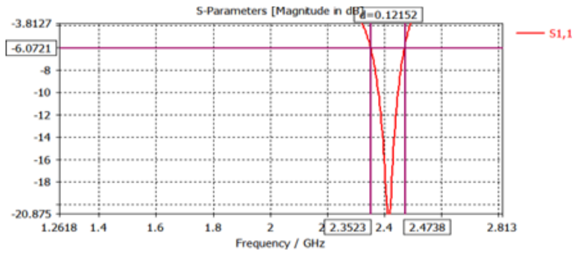


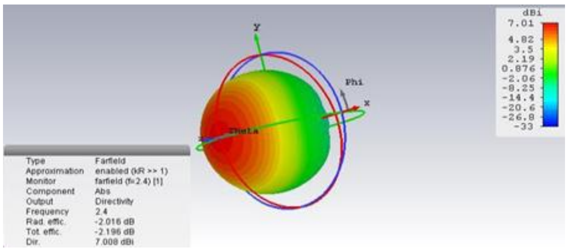
Fig. 12 Bandwidth of single patch antenna with slotte **Fig. 13. Bandwidth of patch antenna array with**

From the figure 13 the antenna bandwidth obtained using slots is up to121 MHz. So it observed in senario 4 the bandwidth of 2x1 slotted patch antenna array is higher than the other senarios.

III. Directivity

Directivity is a measure of the power density the antenna radiates in the direction of its strongest emission. The gain is how well the antenna converts the input power into a radio wave.

A. Scenario 1 and Scenario 2 shows the directivity for a single and 2x1 element patch antenna without slotted. So from the figure 14 and figure 15 below shows given results:



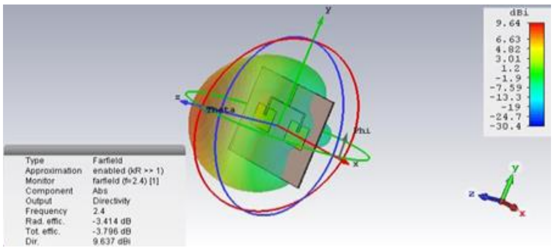
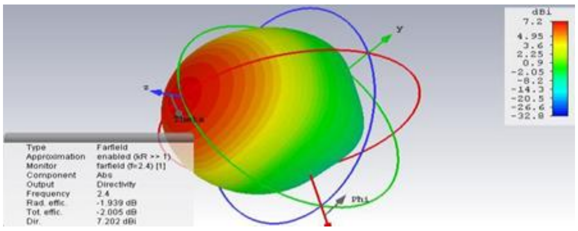


Fig. 14: Directivity plot of single patch antenna. **Fig. 15. Directivity plot of patch antenna array elements.**

B. Scenario 3 and Scenario 4 illustrates the directivity for a single and 2x1 element patch antenna with slotted. So from the figure 16 and figure 17 below shows given results:



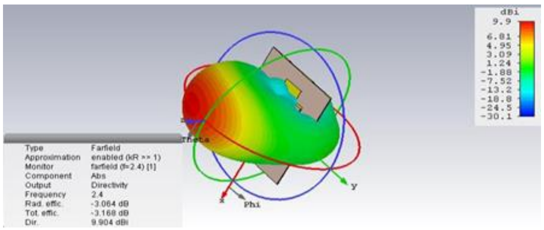


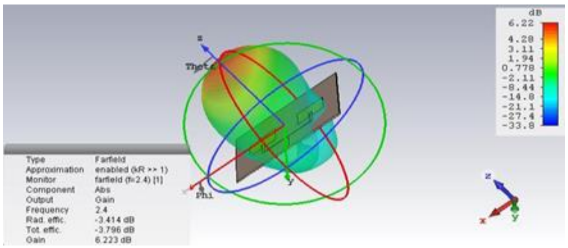
Fig. 16. Directivity plot of singl patch antenna with slots. **Fig. 17. Directivity plot of 2x1 slotted patch. antenna**

In the previous figures, we presented the directivity measurement results in all the designed scenarios, compared the scenarios, and observed how the ground defect technique improved the directivity of the antenna.

IV. Gain

This is the direction in which there is more radiation or this is a measure of the ability of an antenna to direct the input power into radiation in a particular direction and also measured at the peak radiation intensity.

A. Scenario 1 and Scenario 2 shows the gain for a single and 2x1 element patch antenna without slotted. So from the figure 18 and figure 19 below shows given results:



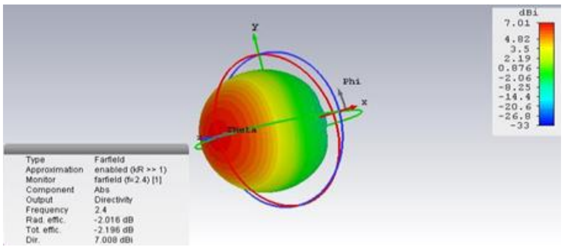
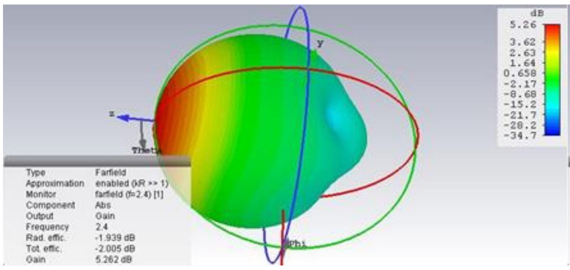


Fig. 18. Gain plot of single patch antenna without slots. **Fig' 19. Gain plot of 2x1 patch antenna slots**

B. Scenario 3 and Scenario 4 illustrates the gain for a single and 2x1 element patch antenna with slotted. So from the figure 20 and figure 21 below shows given results:



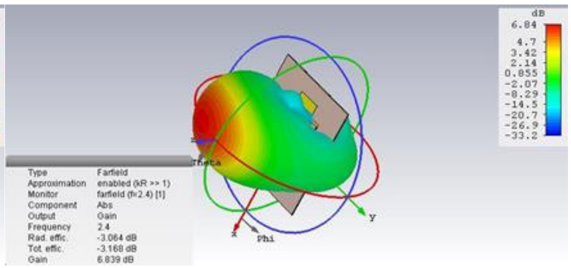


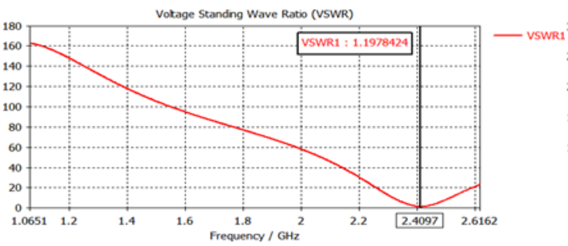
Fig. 20. Gain plot of singl patch antenna with slots **Fig. 21. Gain plot of 2x1 patch antenna array with slot**

In the previous results shows achieved improved antenna by using DGS. So it is noticed that the best result obtained is in the scenario 4 by using defected in the ground were was 6.8dB.

V. Voltage Standing Wave Ratio (VSWR)

VSWR is the ratio between the maximum voltage and minimum voltage the transmission line.

A. Scenario 1 and Scenario 2 shows the VSWR for a single and 2x1 element patch antenna without slotted. So from the figure 22 and figure 23 below shows given results:



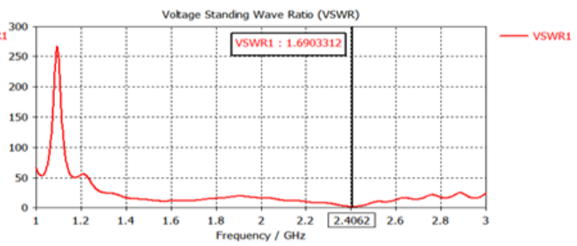
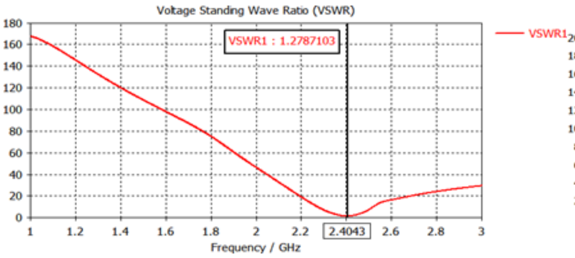


Fig.22: VSWR for a single patch antenna without slots **Fig.23: VSWR for 2x1 patch antenna without slots.**

B. Scenario 3 and Scenario 4 illustrates the VSWR for a single and 2x1 element patch antenna with slotted. So from the figure 24 and figure 25 below shows given results:



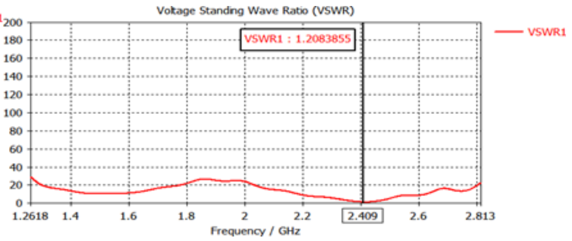


Figure 24. VSWR plot of a singl patch antenna with slots Figure 25. VSWR plot of slotted 2x1 patch antenna ary

This is the ratio of the maximum value of the standing wave voltage to its minimum value. The minimum VSWR of the antenna will be 1. An antenna with less VSWR has a better return loss compared to the other antenna. we noticed that the best result obtained in the first senario were was 1.19.

VI. Comparative Study Of All scenarios results:

Table 2 shows results and achieved improved antenna by using DGS for all scenarios.

Table 2: show The comparison between all scenarios

parameter	Scenario 1 Without DGS	Scenario 2 With DGS	Scenario 3 Without DGS	Scenario 4 With DGS
Return loss	-20 dB	-11.8 dB	-16.4 dB	-20.8 dB
Bandwidth	70 MHz	90 MHz	105 MHz	121MHz
Gain	4.99 dB	6.22 dB	5.2 dB	6.8 dB
Directivity	7dBi	9.6 dBi	7.2 dBi	9.9 dB
VSWR	1.19	1.6	1.2	1.2

After we have analyzed all the four scenarios, From the table 2 it can be seen that array configuration gives much higher gain,directivity, bandwidth characteristics than single patch. Also, single and array patch antenna with slots has better gain, bandwidth, directivity characteristics. The bandwidth for single patch antenna without slots is 70 MHz and 90 MHz for the antenna array without slots, respectively whereas the bandwidth of single patch antenna with slots is approximately 105 MHz This shows that the bandwidth of single patch antenna with slots is enhanced approximately 35 MHz with respect to conventional antenna. 2x1 array has improved results over single antenna while 2x1 patch array with slots provided further improved results than 2x1 array without slots were that the bandwidth obtained using slots is up to121 MHz. After comparing the results of all scenarios, slotted patch array antenna comes out to be the best bandwidth out of all four scenarios.

5. CONCLUSION

The patch antenna for all scenarios has been successfully designed, and tested. The results were obtained and analyzed and were in agreement with the theory. The characteristics of the patch antenna were found and then discussed where the results were analyzed.
microstrip patch antenna without slots and with slots are designed and simulated at operating frequency 2.4 GHz. The software test results are found to be satisfactory and antenna can be used for 2.4 GHz ISM frequency band applications like Bluetooth, WLAN etc. Implementing slots in the ground in microstrip patch results in improved bandwidth. Practically bandwidth obtained using slots is up to121 MHz. Along with bandwidth other

parameters like uniform current distribution, beam width ,return loss ,reflection coefficient ,VSWR , are also improved. The microstrip antenna without slots, the bandwidth is narrow and the return loss is high, microstrip antenna with slots will provide higher operating bandwidth and less return loss. After comparing the results of all scenarios we have seen that
The best design was in scenario 4.

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