CHAPTER 4

DESIGN OF BROADBAND MICROSTRIP ANTENNA USING PARASITIC STRIPS WITH BAND-NOTCH CHARACTERISTIC

4.1 INTRODUCTION

Wireless communication technology has been developed very fast in the last few years. A conventional microstrip antenna suffered narrow impedance bandwidth [22]. Therefore, various approaches have been proposed to increase the bandwidth such as Annular Ring antenna [23], Band notch slot patch antenna [24], and band-notched folded strip monopole antenna [25]. Broadband applications require the rejection of the interference with narrow frequency bands such as wireless local area network (WLAN).

Beside the above mention, Broadband antennas are designed with Square ring with a pair of T-shaped strip [26], antenna design using EBG structure [27], parasitic strip rectangular microstrip monopole antenna [28], compact disc monopole antenna [29], Microstrip antenna using slotted partial ground and addition of stairs and stubs [30], parasitic patch [33] and antenna design with I shaped band-notched parasitic element [49] to achieve wide fractional bandwidths with band notch characteristic. That’s why microstrip patch antenna can be design with these designing techniques to achieve band-notch characteristics and wide bandwidth. But there are some challenges which are faced by antenna designer to achieving radiation stability, reducing the antenna size and minimizing interference with other wireless system such as WLAN. In this chapter one such reference antenna geometry by Hsien-Wen Liu is presented [22]. The reference antenna is covered frequency range from 3.05 GHz to 11.15 GHz or percentage bandwidth of 114% with rejection in frequency band from 5.12 GHz to 6.08 GHz. The aim of my work is to increase this percentage bandwidth upto 150% with rejection in WLAN frequency range nearly close to 5.15 GHz to 5.825 GHz using parasitic strips.

4.2 DESIGN METHODOLOGY

In order to design Broadband microstrip antenna using parasitic strips with band-notched Characteristic, the designing method is divided into subtasks. The flow chart as shown in Fig. 4.1 explains the process.
Planar microstrip antennas are of low profile, small size, and comfortably fabricate on the printed circuit board (PCB). For this reason, broadband band rejection design techniques for microstrip patch antennas have been attracted much attention from antenna researchers. According to the literature survey on microstrip patch antenna design, it is found that microstrip patch antennas mostly designed using FR4 as a substrate material with a dielectric constant of 4.4 (i.e., $\varepsilon_r = 4.4$), a loss tangent of 0.02 (i.e., $\tan\delta = 0.02$), a thickness of 1.6mm (i.e., $h = 1.6$ mm) and an input impedance of 50 ohms (i.e., $R_{in} = 50\Omega$).
4.3 ANTENNA DESIGN

The square patch is analyzed and designed using the transmission line model in this reference antenna design, and then its design is optimized using the HFSS that computes the radiation parameters. In this antenna design a compact planar monopole antenna with band-notched characteristic is presented. By using the strip at the center of the patch, operating band from 3.05 GHz to 11.15 GHz can be obtained with good frequency rejection.

![Fig.4.2. Geometry of band-notched microstrip patch antenna [22]](image)

All the above mentioned symbols depicted in above figure are illustrated in table 4.1.
Table 4.1: Dimensions of band-notched microstrip patch antenna [25]

Fig. 4.2 shows the band-notched microstrip antenna geometry with design parameters. For good impedance matching spacing between the slot patch and the ground plane $G_2$ optimized to 1 mm coupling strip placed at the center of the slot patch is responsible for stop band operation. The reference antenna has operating band from 3.05 GHz to 11.15 GHz, rejecting the frequency band from 5.12 GHZ to 6.08 GHz as shown in Fig. 4.3.
4.4 PROPOSED MODIFICATIONS IN ANTENNA DESIGN

Hsien-Wen Liu presented a compact monopole antenna geometry as shown in Fig. 4.2. The antenna covered wide frequency range from 3.05 GHz – 11.15 GHz i.e. percentage bandwidth of 114 % with rejection in frequency band from 5.12 GHz - 6.08 GHz.

The aim of my work is to achieve percentage bandwidth of greater than 150 % and reject the WLAN frequency range from 5.15 GHz to 5.825 GHz. To achieve this aim, one antenna design technique is investigated i.e. design of an antenna using parasitic strips. In this modified antenna design, the square slot and vertical strip have been removed. The geometry of antenna designing parameters such as substrate length and width and feed line width are selected from the reference antenna geometry given by Hsien-Wen Liu.

The effective dielectric constant, width and length are calculated using equations 1.1-1.6 as discussed in chapter 1. While changes are made in patch dimension to obtain resonating frequency so that desire center frequency of notch band can be obtained at resonating frequency 4.56 GHz. In first geometry of antenna with full ground plane is
designed and result of this antenna design is that the broadband microstrip antenna characteristics are not achieved as discussed in section 4.4.1.

An appropriate change in ground plane is made to obtain broadband microstrip antenna characteristics. In second geometry of antenna with partial ground plane is designed and result of this antenna design is that broad bandwidth is achieved as discussed in section 4.4.2. In third geometry of antenna to achieve band-notch characteristic, parasitic strips are placed on the bottom side of substrate. These parasitic strips are coupled with ground plane to create band dispensation for WLAN system. The antenna design with parasitic strips is presented in section 4.4.3 in detailed. The effect of parasitic strips is that, band notch is introduced in order to stop the function of the antenna in particular frequency range from 5.15 GHz – 5.83 GHz. The band rejection feature of antenna can minimize the potential interference between broadband system and WLAN systems. Parasitic strips helped me to avoid the use of the band stop filters and hence reducing the cost and complexity of the antenna [28].

Designing process is discussed in detail as:

**4.4.1 Antenna Design with Full Ground Plane**

A simple microstrip square patch antenna is designed with FR4 epoxy dielectric substrate as shown in Fig. 4.4. The full ground plane is used at the bottom of the substrate and ground plane size is same as the substrate size.

![Fig.4.4. Geometry of microstrip patch antenna with full ground plane](image)
A microstrip feed line is designed for 50 ohm characteristic impedance with 3.2 mm wide in order to fulfill the requirements of a portable device. This arrangement is allowed to flow of surface current through the feed-line and concentrates the surface current around the bottom of the radiating patch.

All the above mentioned symbols depicted in above figure are illustrated below in table 4.2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate width, $W_s$</td>
<td>30 mm</td>
</tr>
<tr>
<td>Substrate length, $L_s$</td>
<td>35 mm</td>
</tr>
<tr>
<td>Patch width, $W_p$</td>
<td>11.5 mm</td>
</tr>
<tr>
<td>Patch length, $L_p$</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Feedline width, $W_f$</td>
<td>3.2 mm</td>
</tr>
<tr>
<td>Feedline length, $L_f$</td>
<td>13 mm</td>
</tr>
</tbody>
</table>

Table 4.2: Dimensions of microstrip patch antenna with full ground

4.4.1.1 Simulation Results

![Graph showing Return Loss vs. Frequency](image)

**Fig. 4.5.** Return Loss vs. Frequency graph of antenna with full ground plane
The return loss of optimized microstrip patch antenna with full ground plane is shown in figure 4.5. When the ground plane size is equal to the substrate size, return loss values are not satisfactory. Antenna has a narrow bandwidth of 2.39 GHz with in frequency range from 11.17 GHz to 13.56 GHz and resonant frequency is 11.81 with $S_{11} = -24.05$ dB. Result of this design is that broadband characteristic of microstrip antenna is not achieved. To obtain broadband microstrip antenna characteristics changes are made in ground plane length and reducing the ground plane length upto the point where the desired broad bandwidth is achieved.

4.4.2 Antenna Design with Partial Ground Plane

Antenna design with full ground plane does not fulfill the requirement of broadband microstrip antenna, that’s why changes are made in ground plane length to achieve good broadband characteristic. It is found that partial ground plane shows better return loss compared to full ground plane based on the parametric study done on the length of the ground plane it is because using the partial ground plane the antenna is transformed from patch type to monopole type. Reducing the ground plane length upto the point where the patch edge is just above the ground plane thereby providing no distance for distribution of electric and magnetic field energies which in turn results in no impedance matching between the transmission line and the patch. On further reducing the ground plane length such that distance is created between the patch edge and the ground plane. Length of ground plane is decreased from 35 mm to below the edge of the patch as 11.4 mm and the required broad bandwidth is obtained. When length of ground plane is decreased below 11.4 mm then bandwidth of antenna is also decreased (discussed in section of parametric study 4.6).
4.4.2.1 Simulation Results

The simulated results of return loss and VSWR of optimized rectangular microstrip patch antenna is presented in Fig. 4.7(a) and 4.7(b) respectively. According to figure 4.7(a), the antenna has broadband characteristic i.e. frequency band of 1.26 GHz – 11.6 GHz and bandwidth of 10.34 GHz. The antenna has resonating frequencies at 2.4 GHz with \( S_{11} = -16.21 \, \text{dB} \) and 7.5 GHz with \( S_{11} = -21.62 \, \text{dB} \). Fig. 4.7(b) shows the simulated VSWR of the antenna with partial ground plane as a function of frequency. VSWR of antenna in the entire bandwidth range from 1.26 GHz to 11.6 GHz is well within desired 2:1 VSWR ratio.

Fig. 4.7. (a) Return Loss vs. Frequency graph for antenna with partial ground plane
The rectangular microstrip patch antenna with partial ground provides operational bandwidth from 1.26 GHz to 11.6 GHz which covers the wide bandwidth of 160% but does not provide rejection from WLAN range to reduce interference with WLAN systems. To obtain band dispensation characteristic, parasitic strips are introduced.

4.4.3 Antenna Design with Parasitic Strips

The antenna with partial ground plane is able to achieve wide frequency range from 1.26 GHz to 11.6 GHz. But WLAN frequency range from 5.15 GHz to 5.825 GHz exists in this wide frequency range and causes interference to WPAN devices. Many approaches are discussed above to reject this frequency band and stop the function of the antenna in this particular frequency range. So design an antenna with compact size, light weight and broadband width is an important issue. One of the techniques is to design an antenna with parasitic strips. In this design methodology, antenna is designed initially with one parasitic strip. Strip is placed at the bottom of the substrate near to the ground plane. The strip is positioned in the center of the substrate. Initially Strip length $L_x = 7.9$ mm and width $W_x = 3$ mm are selected from the Hsien-Wen Liu antenna design. Return loss graph is obtained from the HFSS software as shown in Fig. 4.17. Effect of this strip is that notch frequency range is not generated. Therefore only adding one more strip in left side, parallel to center strip and gap is maintained as 2 mm between both strips. Strips are coupled with ground plane. Length, width and position of both strips are changed as per
the requirement to achieve notch frequency range. From the simulated result notching is generated but notch frequency range is not obtained as shown in Fig. 4.10. To obtain this notch frequency range from the operating range of antenna, one more strip is added in right side, parallel to center strips at 2 mm distance from the center strip. Now three parasitic strips are placed at bottom of the substrate and coupled with ground plane. Effect of these strips is that notch frequency is generated. But to obtain notch frequency range nearly close to WLAN frequency range, Length, width and distances between these strips are obtained from the parametric study. Desired distances between strips are obtained by movement of left and right side strips in x direction as discussed in section 4.6. Length and Width of strips are obtained as 17 mm and 1 mm respectively and distances \(d_1\) and \(d_2\) between strips are 3 mm and 4 mm respectively. At these distances left and right side strips are positioned at \(x = -5\) and \(x = 5\) respectively and center strip is positioned at \(x = -1\) as discussed in parametric study. Distance between parasitic strips and ground length is 0.2 mm as shown in table 4.3. Effect of these three parasitic strips is that the notch frequency range is obtained. Effect of adding one more strip parallel to all three strips is that four parasitic strips are not creating any changes to notch frequency range. Antenna is designed with three parasitic strips as shown in Fig. 4.8.

![Geometry of microstrip patch antenna using parasitic strips coupled with ground plane](image)

**Fig.4.8.** Geometry of microstrip patch antenna using parasitic strips coupled with ground plane
All the above mentioned symbols depicted in above figure are illustrated below in table 4.3.

<table>
<thead>
<tr>
<th>Parameter</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Substrate width, $W_s$</td>
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</tr>
<tr>
<td>Substrate length, $L_s$</td>
<td>35 mm</td>
</tr>
<tr>
<td>Patch width, $W_p$</td>
<td>11.5 mm</td>
</tr>
<tr>
<td>Patch length, $L_p$</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Feedline width, $W_f$</td>
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</tr>
<tr>
<td>Feedline length, $L_f$</td>
<td>13 mm</td>
</tr>
<tr>
<td>Ground plane length, $L_g$</td>
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</tr>
<tr>
<td>---------------------------</td>
<td>-------</td>
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<tr>
<td>Strips length, $L_x$</td>
<td>17 mm</td>
</tr>
<tr>
<td>Strips width, $W_x$</td>
<td>1 mm</td>
</tr>
<tr>
<td>Gap between left and center strips, $d_1$</td>
<td>3 mm</td>
</tr>
<tr>
<td>Gap between right and center strips, $d_2$</td>
<td>4 mm</td>
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<tr>
<td>Gap between strips and ground plane, $a$</td>
<td>0.2 mm</td>
</tr>
</tbody>
</table>

Table 4.3: Dimensions of proposed antenna using parasitic strips

4.4.3.1 Simulation Results

The simulated result of return loss and VSWR of the microstrip patch antenna with parasitic strips is presented in Fig. 4.10 (a) and 4.10 (b) respectively. From the Fig. 4.10 (a), the proposed antenna has a bandwidth of 8.63 GHz ranging from 1.12 GHz - 9.75 GHz and WLAN band is rejected in the range from 5.15 GHz - 5.83 GHz. The percentage bandwidth of antenna is 158 %. The presence of parasitic strips at the bottom of the substrate caused a band notch in frequency range from 5.15 GHz to 5.83 GHz. VSWR graph of proposed antenna which is less than 2 for entire operating bandwidth except the range 5.15 GHz - 5.83 GHz. The antenna has impedance matching at resonance frequencies 4.56 GHz with $S_{11} = -26.32$ dB and 7.4 GHz with $S_{11} = -39.93$ dB using microstrip line feed.
Fig. 4.10. (a) Return Loss vs. Frequency graph for proposed antenna

Fig. 4.10. (b) VSWR vs. Frequency Graph for proposed antenna

After discussion on band notch characteristics of WLAN frequency band, far field radiation characteristics of antenna is also studied. An electric field pattern is formed because the alternating electric current enters the antenna through the feed line-patch junction and leaves the antenna through the radiating edge of the patch and hence having maximum field at the radiating edges of the patch in the direction of radiation and
minimum field at the center of the patch hence a dumbbell shaped radiation pattern is formed.

Fig. 4.11. Radiation pattern at frequency 1.12 GHz

Fig. 4.12. Radiation pattern at frequency 4.56 GHz
Fig. 4.11, 4.12 and 4.13 shows that simulated radiation patterns at frequencies 1.12 GHz, 4.56 GHz and 7.4 GHz. The Dumbbell shaped radiation pattern is obtained at frequency 1.12 GHz. The radiation patterns of antenna have bidirectional property.

4.5 ANALYSIS ON LENGTH, WIDTH AND POSITION OF PARASITIC STRIPS

Band notch frequency range is generated by placing parasitic strips. Notch frequency range is changed by change in strips length, width and position of strips. The relation is generated between frequency ratio \((f_{un} - f_{ln})/f_o\) (where \(f_{un}\) is upper notch frequency, \(f_{ln}\) is lower notch frequency and \(f_o\) is resonant frequency) and normalized strips length, width, and position of the strips. Normalized value of strips length is the ratio of strips length to guided wavelength \((L_x/\lambda_g)\) is shown in Fig. 4.14.
Fig. 4.14. Graph between frequency ratio \( \frac{f_{\text{un}}-f_{\text{ln}}}{f_{\text{o}}} \) and strips length to guide wavelength \( L_x/\lambda_g \).

The graph is plotted by varying normalized length of strips while keeping width and position of strip as constant at resonant frequency 4.56 GHz. As the normalized length of strips is increased from 0.50 to .56 then the lower and upper edge frequency change with very small value but the frequency ratio is increased. When the normalized length is 0.5 the notch band has range from 5.3 GHz to 5.89 GHz which does not match with objective. When normalized length of strips is increased to 0.52 a band notch of 5.24 GHz – 5.87 GHz. Increment in strips normalized length from 0.52 to 0.54, caused a band notch range from 5.15 GHz to 5.83 GHz which is required range for WLAN rejection and fulfill our objective also. Further increment in strips normalized length i.e. 0.56 caused a band notch range from 4.9 GHz to 5.68 GHz which is not acceptable. Fig. 4.14 shows the graph and it helps in estimating the normalized strips length to achieve the desired notch band.

Normalized value of strips width is the ratio of strips width to guided wavelength \( W_x/\lambda_g \) is shown in Fig. 4.15.


**Fig. 4.15.** Graph between frequency ratio \((f_{un}-f_{ln})/f_{o}\) and ratio of strips width to guide wavelength \((W_x/\lambda_g)\)

The graph is plotted by varying normalized width of strips while keeping length and position of strip constant at resonant frequency 4.56 GHz. As the normalized width of strips is increased from 0.01 to 0.07 frequency ratio is increased (Distances between strips are changed due to width increment but in proposed antenna design distance between strips are obtained by movement of left and right side strips in x direction as discussed in section 4.6). When the normalized width is 0.01 then notch band has range from 5.16 GHz to 5.76 GHz which does not match with objective. When normalized width of strips is increased as 0.03 then band notch of 5.15 GHz – 5.83 GHz with frequency band of 1.12 GHz – 9.75 GHz is obtained. Further increment in normalized width of strips as 0.05 and 0.07, caused a band notch of 5.14 GHz - 5.87 GHz and 5.1 GHz - 5.9 GHz which is not acceptable. Fig. 4.15 is design curve and it helps in estimating the normalized strips width to achieve the desired notch band.
Fig. 4.16. Graph between frequency ratio \((f_{un}-f_{in})/f_{o}\) and ratio of center strip position to guide wavelength \((x/\lambda_g)\)

Normalized value of center strip position is the ratio of position to guided wavelength \((x/\lambda_g)\) is shown in Fig. 4.16. The graph is plotted by varying position of center strip while keeping strips width and length constant at \(W_x = 1\) mm and \(L_x = 17\) mm respectively at resonant frequency 4.56 GHz. As the normalized position of center strip is increased from centre of substrate the frequency ratio first decreased and then increased.

When the normalized position of center strip is changed from 0 to 0.06 then frequency ratio first decreased and then increased. When the normalized position of strip is 0; achieved band notch is from 5.17 GHz to 5.87 GHz which causes interference with WLAN system (range of 5.15 GHz – 5.825 GHz). For further improvement in band dispensation characteristic normalized strip position is changed in negative x direction from the center of substrate. When normalized position of strip is 0.01 the band notch is 5.16 GHz - 5.85 GHz which again causes interference. As the normalized strip position is changed from 0.01 to 0.3, the frequency range 5.15 GHz - 5.83 GHz is notched which is nearly closed to WLAN system. Further movement in normalized position of strip i.e. at 0.04 and 0.06 mm, notch band of 5.14 GHz – 5.73 GHz and 5.13 GHz -5.74 are achieved which is not suitable range. Similarly normalized strip position is changed in positive x direction from the center of substrate. At 0.01 the band notch is 5.12 GHz - 5.8 GHz. When the normalized position of strip is changed as 0.03 and 0.04, the notch frequency
ranges are achieved as 5.05 GHz - 5.65 GHz and 5.04 GHz - 5.63 GHz respectively. Further change in normalized strip position i.e. 0.06 notch band is increased from 5.04 GHz – 5.64 GHz due to this frequency ratio is also increased which is not suitable range. Fig. 4.16 is design curve and it helps in estimating the normalized the center strip position to achieve the desired notch band. When both distance \(d_1\) and \(d_2\) between strips are changed together then band notch bandwidth is also changed discussed in section of parametric study 4.6.

From the whole analysis on relation between frequency ratio \((f_{un} - f_{ln})/f_o\) (where \(f_{un}\) is upper notch frequency, \(f_{ln}\) is lower notch frequency and \(f_o\) is resonant frequency) and normalized length, width and strip position to guide wavelength. It can be concluded that when normalized width of strips is increased then wide variation in notch bandwidth is achieved at resonant frequency 4.56 GHz. Further increment in strips normalized width is that notch bandwidth is increased which is not closed to WLAN frequency range. When normalized length of strips is increased then notch frequency range is shifted in left side which is also effected the notch bandwidth and increased the frequency ratio. When change is normalized position of strip then notch frequency range is shifted in left side. (Distances between strips are changed due to change in center strip position but in antenna design distances between strips are obtained by movement of left and right side strips in x direction as discussed in section 4.6). Thus curves of normalized length, width and position of Parasitic strips are helped me to obtained the desired notch band from 5.15 GHz to 5.83 GHz.

**4.6 PARAMETRIC STUDY**

The parametric study is done to obtain desired operating bandwidth and notch band with change in dimensions of ground plane length and parasitic strips length, width and position. Parasitic strips width, length, position, distance between strips and ground plane length are optimized by parametric study. The desired operating bandwidth can be obtained by change in ground plane length. The desired notched frequency range and bandwidth of notched band can be controlled by proper selection of parasitic strips dimensions which are simulated by electromagnetic software HFSS. The effect of ground plane length \(L_g\), effect of adding one, two and three parasitic strips effect of width \(W_x\)
with length $L_x$ and effect of distance $d_1$ and $d_2$ between strips on VSWR are studied. After the parametric study, find that these are the optimum conditions for the antenna to work properly.

4.6.1 Effect of Ground Length

Antenna design with full ground plane not fulfilled the requirement of Broadband microstrip antenna, that’s why the ground plane length is reduced upto the point where the patch edge is just above the ground plane thereby providing no distance for

![VSWR graph showing effect of $L_g$ with 10 mm, 11.4 mm, 11.6 mm](image)

**Fig. 4.17.** VSWR graph showing effect of $L_g$ with 10 mm, 11.4 mm, 11.6 mm distribution of electric and magnetic field energies which in turn results in no impedance matching between the transmission line and the patch. The ground plane length is reduced such that distance is created between the patch edge and the ground plane. That’s why ground length $L_g$ is decreased from 13.4 mm to 10.4 mm, effect of this decrement is that the operating bandwidth is increased. As $L_g$ is reduced to 13.4 mm the frequency band is 11.2 GHz to 13.6 GHz but it does not provide broad bandwidth. Reduction in length of ground to 12.4 mm then operational broad bandwidth is not obtained. When reduction in length of ground plane is 11.4 mm then wide bandwidth 10.34 GHz with frequency band 1.26 GHz to 11.6 GHz is achieved. Again reduction in length from 11.4
mm to 10.4 mm then frequency band is decreased from 1.26 GHz to 10 GHz. Fig. 4.17 is design graph and it helps to achieve the desired operating bandwidth.

After the parametric study of length of the ground plane it is found that $L_g = 11.4$ mm is the optimum conditions for the proposed antenna to work properly.

**4.6.2 Effect of Adding Strips**

Antenna is designed initially with one parasitic strip. Strip is placed at the bottom of the substrate near to the ground plane. Effect of this strip is that notch frequency range is not generated. That’s why adding one more strip, parallel to previous strip and both strips are coupled with ground plane. Effect of two strips is that notching is generated but notch frequency range is not obtained. To reject this notch frequency range from the operating range of antenna, one more strip is added parallel to both strips. Now three parasitic strips are placed at bottom of the substrate and coupled with ground plane. Effect of these three parasitic strips is that notch frequency range is obtained as shown in Fig. 4.18.

![Return Loss graph showing the effect of adding one, two and three strips](image)

**Fig. 4.18.** Return Loss graph showing the effect of adding one, two and three strips
After the parametric study of parasitic strips, it is observed that the effect of adding three strips at the bottom of the ground plane are the optimum conditions for the proposed antenna to work properly.

### 4.6.3 Effect of Strips Width and Length

Effect of three parasitic strips is that notching in operating frequency band is generated and variation in width and length of three strips are made to find optimum condition for antenna to work properly. The distances between strips are constant at this time. When strips width $W_x$ is increased from 0.5 mm to 1.5 mm and strips length $L_x$ is increased from 16.5 mm to 17.5 mm then the notched bandwidth increases on frequency axis from 0.5 GHz to 1 GHz as shown in Fig. 4.19.

![VSWR graph showing effect of $W_x$ with $L_x$.](image)

**Fig. 4.19** VSWR graph showing effect of $W_x$ with 0.1 mm, 1 mm, 1.5 mm and $L_x$ 16.5 mm, 17 mm, 17.3 mm

Effect of more increment in width and length of parasitic strips is that notched bandwidth is increased and operating bandwidth is decreased and antenna is not operated in desired broad frequency range with rejection in nearly close to WLAN frequency range. After the parametric study of width and length of the parasitic strips the desired width and length as $W_x = 1$ mm and $L_x = 17$ mm is found with width to length ratio of strip is 1:17.
4.6.4 Effect of Distance $D_1$ and $D_2$ between Parasitic Strips

Effect of adding parasitic strips on the bottom layer of substrate is created band-notch frequency range. The notch frequency range is obtained by varying position of left and right side strips. The width and length of parasitic strip is constant at this time. When positions of left and right side strips are changed then distances between strips are also changed. Thus by varying distances between strips the undesired frequency band has been rejected. Effect of adding strips at the same distance is that notch band is not obtained. That’s why changes are made in distances $d_1$ and $d_2$ to obtain notch frequency range very close to WLAN frequency range. As the distances $d_1$ and $d_2$ between parasitic strips are increased from 2 mm to 4 mm and 3 mm to 5 mm, notched bandwidth is increased from 0.6 GHz to 1.3 GHz as shown in Fig. 4.20.

![Fig. 4.20. VSWR graph showing effect of $d_1$ and $d_2$ with 2, 3, 4 mm and 3, 4, 5 mm respectively](image)

After the parametric study of distances $d_1$ and $d_2$ between the parasitic strips are obtained. At these distances left and right side strips are positioned at $x = -5$ and $x = 5$ respectively and center strip is positioned at $x = -1$. The distances $d_1 = 3$ mm and $d_2 = 4$ mm are found as the desired distances for the proposed antenna to work properly.
4.7 DISCUSSION

Due to increased applications requirement for wide bandwidth with WLAN band rejection, the work has been done on the reference antenna which is already having the percentage bandwidth of 114 %.
The objective is achieved with increased bandwidth upto 158 % covering frequency range from 1.12 GHz to 9.75 GHz. It is done by placing parasitic strips at the bottom of the substrate and covered wider bandwidth as compared to the reference antenna with WLAN frequency range rejection. This broad bandwidth is required in high data transfer rate for WPAN applications.

In the proposed antenna design, effect of the three parasitic strips on notch bandwidth is studied. It is observed that by adding one and two strips do not fulfill notch-band characteristics. But when three parasitic strips of same size are added at the bottom of the substrate, the desired operating bandwidth is obtained with minimized interference with WLAN system. The length, width, position and distance between the parasitic strips are obtained by parametric study and the desired band notch frequency range is achieved with in operating frequency range. From the reference antenna, notch-frequency range is from 5.12 GHz to 6.08 GHz using square slot patch with a vertical coupling strip and obtained bandwidth as 8.1GHz. The frequency range from 5.15 GHz to 5.83 GHz is rejected which is very close to WLAN frequency range using three parasitic strips placed at bottom of the substrate coupled with ground plane. The wide bandwidth as 8.63 GHz is obtained. The proposed antenna is applicable in portable wireless communication devices such as cell phones, laptops and personal digital assistants.

4.8 CONCLUSION

In wireless communication systems high data rate is required.

One of the main problems in broadband antenna is the interference with narrowband antenna. The interference with existing wireless local area network (WLAN) technologies as reported in IEEE 802.11a standard (5.15GHz–5.825GHz) should be reduced. Therefore, different types of planar broadband antennas have been presented. As the result of the researches, antenna design with different types of slot, parasitic strips coupled with radiating patch, ground plane, feed line and two monopoles of same size and a strip to achieve wide bandwidth with band notch characteristic. In this thesis the
band-rejection characteristic is achieved by the placement of three parasitic strips with same size at different positions on the bottom of the substrate. It is observed that adding one and two strips are not sufficient to obtain notch-band characteristics. But when three parasitic strips are added at the bottom of the substrate of same size, It obtained not only the desired operating bandwidth but also minimize the interference with WLAN system. The length, width, position and distance between the parasitic strips are obtained by parametric study and the desired band notch frequency range is achieved with in operating frequency range. From the reference antenna, notch-frequency range is rejected from 5.12 GHz to 6.08 GHz using square slot patch with a vertical coupling strip and obtained bandwidth as 8.1 GHz. It rejected notch frequency range from 5.15 GHz to 5.83 GHz which is very close to WLAN frequency range using three parasitic strips placed at bottom of the substrate coupled with ground plane. It gives wide bandwidth as 8.63 GHz. The return loss, VSWR and radiation pattern of proposed antenna has satisfactory values within operating frequency band. The proposed antenna shows the suppression of WLAN band without extra circuitry. The future scope of the proposed antenna is that it will be applicable in high data transfer rate for WPAN applications.

**FUTURE WORK**

The work presented has some limitations, so future work can be carried out in the following areas:

In future, fabrication of proposed antenna will be carried out and measured results will be compared with simulated results. In second aspect the geometry of antenna with RT Duroid will be designed in future.

RT Duroid has lower dielectric constants (2.2) than the FR4 epoxy dielectric constant (4.4) and increases the bandwidth because bandwidth is inversely proportional to dielectric constant or permittivity. RT Duroid gives maximum radiation due to its low dielectric constant. Bandwidth and radiation pattern depends on loss tangent. Loss tangent of RT Duroid is 0.0004 while loss tangent of FR4 epoxy is 0.02, so RT Duroid is good dielectric substrate for microstrip patch antenna. RT Duroid also has highest tensile strength and breakdown voltage due to which it does not succumb to the electrical
pressure easily therefore it does not lose its insulating property. Thus RT Duroid
dielectric material will give better results than FR4 epoxy dielectric material.