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Impact of Slots on the Performance Analysis of Microstrip Antenna.

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Abstract- This paper presents the effect of the position and number of symmetrical slots in the patch on resonant frequency and impedance bandwidth. It is one of the methods for the efficient enhancement of the bandwidth of the patch antenna. The method uses the insertion of slots, slits and notches on the planer patch structure.The microstrip antennas structure has been designed and simulated on FR4 epoxy substrate with a dielectric constant of 4.4 and height of 1.6 mm. This type of study is useful in the designing of compact antennas for wirelesscommunications. The proposed configurations are simulated and analyzed using ADS software package. The radiation pattern, gain, directivity, bandwidthand return loss performance are studied for the analysis of the different configurations. The simulated result will be of useful in the application of wide band radar, and satellite application in the mapping of earth using microwave.

Key words: Bandwidth, Return loss, Gain, Directivity, Slotted patch antenna.

Introduction

Wireless communication system has shown a tremendous growth in the present days. Various personal application of mobile communication, wireless computer link, wireless remotecontrols, wireless personal internetare on arise in today world. The size of electronics needed for wireless applications are shrinking drastically, where as theirfunctionality has increased. The demand for the antennas for these various applications are of small size, lightweight,low cost and integrality with electronic integrated circuits. Microstrip antennas with planer patch configuration meet with the demands of these. The planer microstrip antenna suffers with narrowbandwidth(3-5%) and poor efficiency. Its low bandwidth is not sufficient for most of the wireless applications nowadays. Various methods have been studied and reported to increase the patch antenna impedance bandwidth. This includes employing square ring slot [1], U-shaped slot [2] and meandered ground plane [3]. The effects of notches are also reported in various literatures [4-6]. Others methods include the use of parasitic element [7] and open loop resonator [8]. The improvement in bandwidth can be achieved by etching the slot [9] in ground and patch of Microstrip antenna of proper length and width.In its basic form, a Microstrip patch antenna is consisting of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. In shape of the patch are square, rectangular,

circular, triangular, and elliptical or some other common shape for the simplification of the analysis and performance prediction.

Antenna Structure and Design

The three essential parameters for the design of a rectangular microstrip patch antenna are frequency of operation (*f*), dielectric constant of the substrate (ε_r), and height of the substrate *(h)*.All the dimension of the antenna depends on these three parameters. The resonantfrequency selected for design is 6.0 GHz.The dielectricmaterial selected for the design is FR4-epoxy which has a dielectric constant of 4.4 and loss tangent of 0.027. A substrate with a high dielectricconstant reduces the dimensions of the antenna since the dimensions are inversely proportions to the dielectric constant. The height of the substrate is chosen on the higher side to add the volume and enhancing the bandwidth. Also it is essential that the antenna is not bulky, so the height of the dielectric substrate is selected as 1.6mm. With these values the length and width of the antenna, as calculated from the different sets of equations [10, 11] is come out to be 11.31 mm and 15. 21 mm. taking into account the impedance matching with the microstrip line, the length and width is keep at 12 mm and 16 mm. The simulation was performed in Advanced design Software (ADS) using Momentus method.

In this configuration of a rectangular microstrip patch, three slots have been made as shown in Figure 1. The slots have been carved out normal to the axis of resonating length. The two are in the middle of the patch whereas the third one is near to the non-radiating edge of the antenna.

Fig 1: Prototype of the antenna.

The length and breadth of the three slots are varied and the suitable size is chosen that provide the best result. This antenna has been studied by varying the positon of the slots also. Once the best result is obtained the notches are carved out and the antenna parameters are studied. At last the result is observed with taking two symmetrical slits in between the first and second slots. The dimension of the antenna is tabulated in table 1.

Table 1: Dimension of the Antenna.

Length of the Antenna	12 mm
Width of the Antenna	16 mm
Length of Microstrip line	12 mm
Width of Microstrip line	4 mm
Length of slot	10 mm
Width of slot	0.5 mm
Length of notch	0.5 mm
Width of notch	2 mm
Length of slit	3 mm
Width of slit	0.5 mm

All the dimensions are calculated using the equations [10, 11] and then slight optimization is done on the length and width of the antenna for the broadening. For efficient radiation, the width of the antenna should be more than length of the antenna but less than twice the length of it. Any departure from it results in the degradation of the radiation efficiency and various antenna parameters. The prototype antenna has a rectangular radiating patch of length 12 mm and width of 16 mm on fr4 epoxy substrate. Three identical slots are spaced at integral multiple of λ. In this design, the slot length is $\lambda/10$ and widths are kept very narrow 0.5 mm and the microstrip patch is fed using an impedance matched microstrip line loaded with 50 ohm load.

Result and Discussion

The observation is started with the plain antenna without any slot. This antenna is simulated and its features are observed. By taking optimization using impedance matching technique, the width of 15 mm and 12 mm × 4 mm size of microstrip line are taken. This structure gives a return loss of -35 dB and again of 19%. Now three slots of equal dimension are taken andthey are carvedon the main antenna structure in a systematic manner. Figure 3 below shows the return loss over the frequency range with the different position of the symmetrical slots over the patch antenna.

Initially all the three slots are kept equidistance from each other. The lower most is near to the non-radiating edge of the antenna. The result in this case shows a degradation in the return loss, whereas all other parameters are marginally affected. Now, the distance between the second slot and third slot are doubled and the observation is noticed. The positions of the first and second slots are kept intact. This position gives a good increment in the gain, but the bandwidth drops to 11% only. Directivity and efficiency are marginally changed. Also the return loss is better than its previous case but not come close to the case without slots. In the next observation, the distance between the first and second slots is doubled, and there is no change in the position of the third slots. In this case, both the gain and the return loss increase significantly. Here the return loss is maximized at 35 dB and the gain percentage is increased to28.5 %. No significant changes in the other parameters are observed. Next the first slot is kept at the position of the second slots, and position of the second and third slots are unchanged with respect to the its preceding observation. Here both the return loss and gain drops significantly. By using the different combination of the position with three symmetrical slots, the best result is the obtained when the distance between the first and second slot is doubled with respect to the second and third slot.

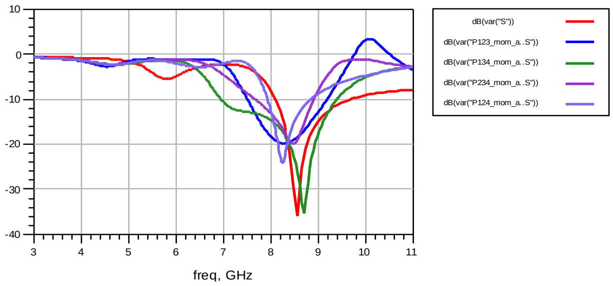


Fig 2: Return loss with the different slot positions

The summary of the results obtained with all these five cases are compared in table 2.

Table 2: Performance analysis with different slot positions.

	Plain	123	124	134	234
Efficiency	28.71	26.51	27.42	26.58	25.97
Directivity (dB)	7.47	7.52	7.57	7.56	7.56
Gain (dB)	1.77	1.79	1.94	1.83	1.69
Bandwidth	19%	20%	11%	28.5%	17.5%
S1 max (dB)	35	20	24	35	20

Any increase in the length or width of the slots degraded the performance of the various parameters specially the return loss and bandwidth. Return loss plot with all these five cases are shown in figure 2. From the plot it is observed that the worst result is obtained when the three slots are at equal distance from each other, and the third one is at the middle. This case accounts for a significant back reflection also. With the insertion of the slots the resonant frequency is shifted towards left as compared to the case without any slots.

Now in the next step the simulations with notches are observed. The best result is obtained with four symmetrical notches at the corners of the patch antenna. With the insertion of the notches, the bandwidth increased to 37%. This is a high rise in the bandwidth. Though the return loss is reduced by 3 dB, but all others parameter shows a marginal improvement. A comparative result is summarized in table 3. S11 plot with plain structure, inserting slots and inserting both slots and notches are shown in figure 3and figure 4 below. in figure 3 the combined result is shown , whereas in figure 4 is the stacked rectangular plot of the three individual cases. From the plot it is observed that with the insertion of notches, the best broadening happens and also the resonant frequency is at 8 GHz, which is near to the central frequency of the design.

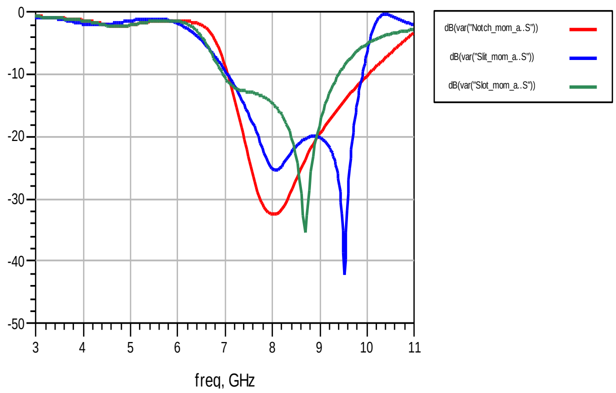


Fig 3: Return loss with the slots, notches and slits.

The last observation is done by inserting two symmetrical slits on the radiating sides of the patch antenna. Here the slits are inserted in between the first and second slots. Though there is no change in the bandwidth is observed, but the return loss is increased by 10 dB with respect to the slot and notch configuration. The high rise in return loss is at the expense of slight reduction in the gain, but this is marginal. Also the insertion of slit shifts the resonant frequency at 9.5 GHz. The resonant frequency is at the center of X Band and its behavior is very sharp.

Table 2 show the performance analysis of the different parameters with the three cases. This gives a clear indication of the effect of notches and slits in enhancing the performance of the antenna parameters.

Table 3: Performance parameter with different structure.

	Slot	Notch	Slit
Efficiency	26.58	27.31	26.48
Directivity (dB)	7.56	7.57	7.53
Gain (dB)	1.80	1.83	1.75
Bandwidth	28.5%	37%	37%
S1 max (dB)	35	32	42

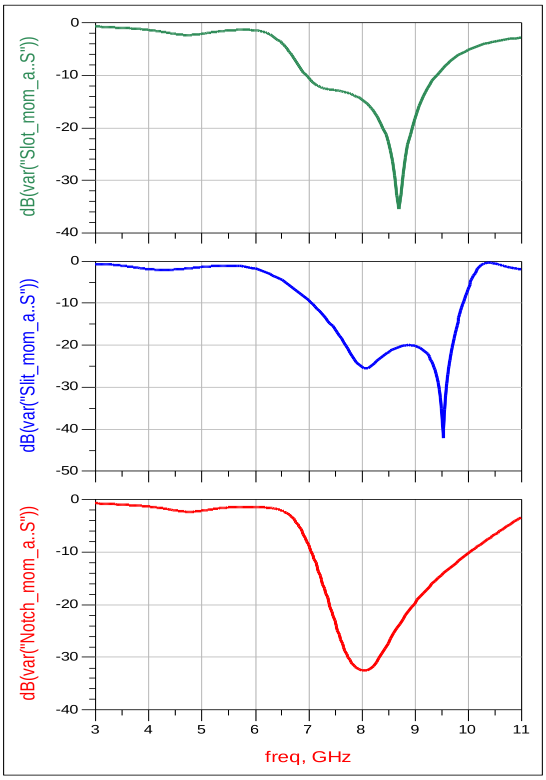


Fig 4: Stacked Rectangular plot with slots, notches and slits.

The current distribution over the patch is shown in figure 5below. In the figure the left one is with slots only. Here it is seen that a signifucant portion of the current is radiated at the junction of patch and line. Any departure of the position of the first slot from the non radiating edge of the patch antenna will impart a poor reflection loss an dmost of current are confined in the line itself. Also here the current distribution is very low near the corners of the edges. But with the introduction of notches, as shown in the middle of the figure, the current distribution at the junction of patch and line reduces and this result in the net increase of the cuurent over the patch. This increases in the current over the patch results in ahigh bandwidth and good return loss with this configuration. But the distrbution of the current is weak in between the first and second slot. So by introducing a small slit of appropiate length the current over this area also increases. The right side of the figure is with the introduction of the slit in between the first and second slots from the non radiating edge.Here over the whole of the patches the current is unoform. The distribution of current and its uniformility over the patch accounts for the high return loss.

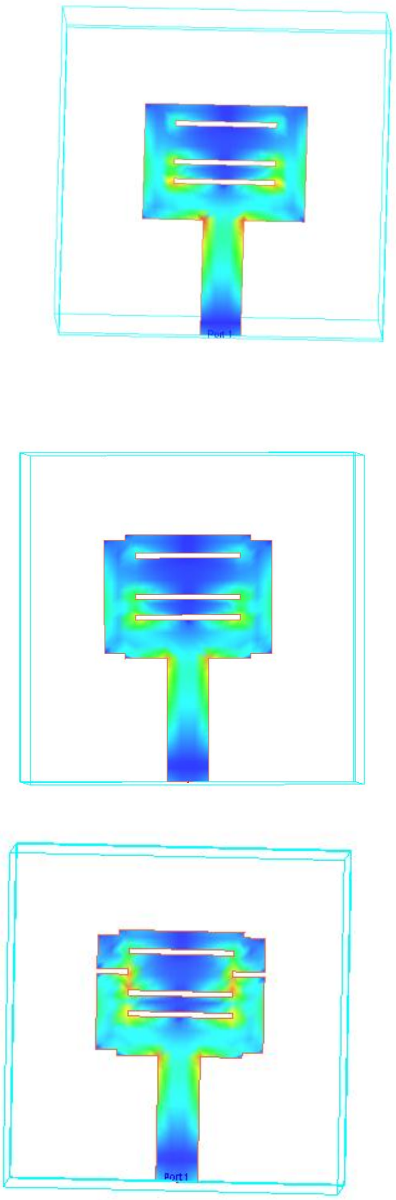


Fig 5: Current distribution of the three types of antenna configuration

The simulated directivity and the gain plot with the three cases along with the 2-dimensional radiation patterns in E-plane of the antenna are shown in figure 6 – 8below. The radiation is symmetric and one directional. The radiation is relatively stable. Both the directivity and the gain are uniformly distributed around the axis. In all the three cases, directional pattern is observed. The maximum directivity and gain is at the centre.

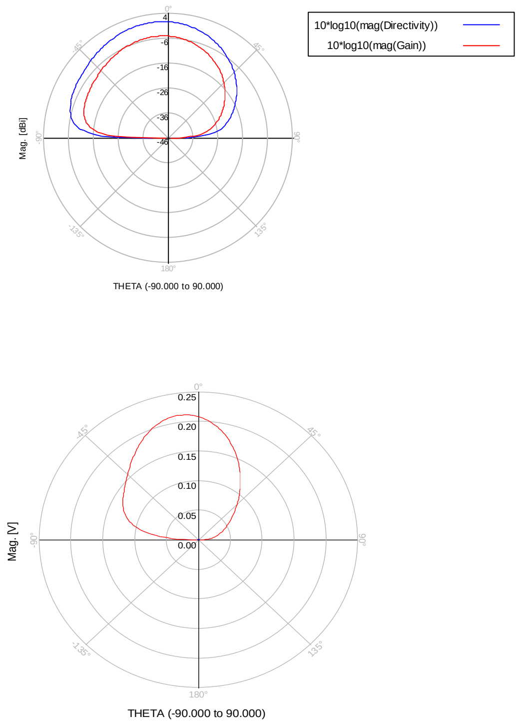


Fig 6: Gain, directivity and E-field with slots only.

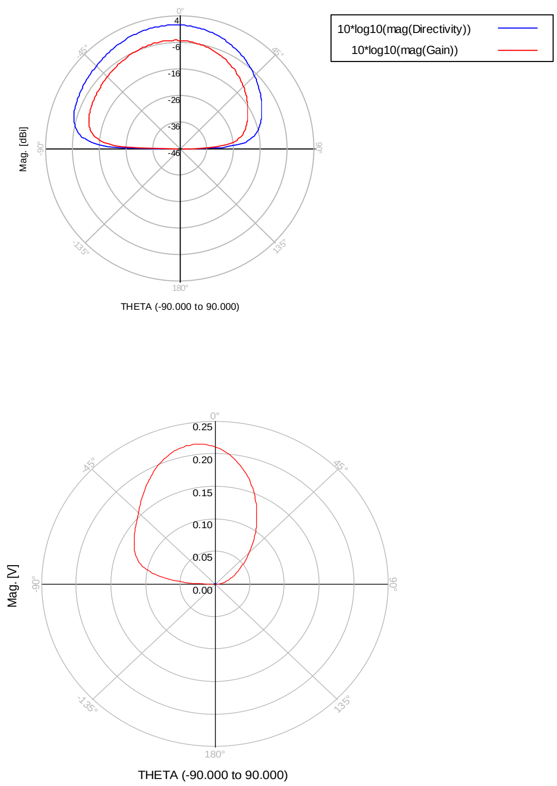
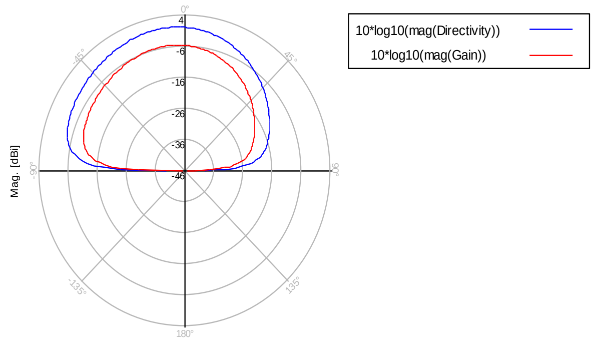


Fig 7: Gain, directivity and E-field with insertion of notches.



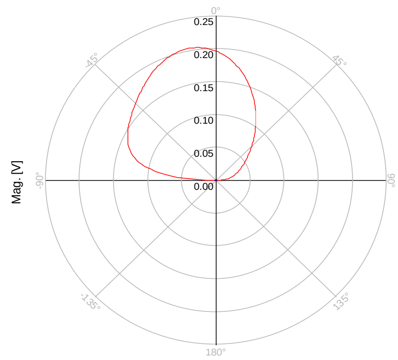


Fig8: Gain, directivity and E-field with insertion of slits.

Conclusion

The Rectangular Microstrip Patch Antenna has been analyzed with the slots, notches and slits onto the patch of the antenna. It is demonstrated with the configuration of the slots the bandwidth improved drastically. When the notches are introduced there is more improvement in the bandwidth though the S_{11} parameter slightly drops. It has been observed that bandwidth and gain are more affected with the notches rather than only slot. The insertion of slits exhibits a high return loss. The return loss variation exhibits impedance match as the function of slot length and width. By proper selection of feed, slot length and width, the antenna performance can be optimized which can be effectively and efficiently utilized for various wide band wireless communications applications.

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