Design Analysis of a Cross - Slot Patch Antenna for Hotspot Applications

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Abstract :

A new design of a patch antenna is proposed for hotspot applications. The antenna is first designed with a rectangular patch. To improve the impedance matching at the resonant frequencies, the position of the patch and the feed are optimized. Further, slots are cut from the patch. The size and position of the slots have also been optimized. The designed patch antenna is simulated in the frequency range 2 GHz to 6 GHz. A compact antenna design is considered. Simulation results for S_{11} parameter, gain, radiation pattern and directivity of the antenna have been shown.

Keywords – *Gain, Patch antenna, Radiation pattern, Slot.*

I. INTRODUCTION

With the growing demands in wireless communication, a patch antenna with its low profile is the most preferable. Other than its light weight and low cost of fabrication [1], [2], it has planar configuration that can easily be mounted on any host surface. A patch antenna is capable of dual and triple frequency operations. It supports vertical, horizontal, right hand circular polarization (RHCP) and left hand circular polarization (LHCP) [3]. An antenna performance is given by some fundamental parameters such as gain, directivity, bandwidth and the radiation pattern [1]. Different techniques for the enhancement of the antenna performance have been studied considerably. Inclusion of slots with near about symmetrical distribution on conducting plane and changing the feed position are some of the techniques for better impedance matching [4], [5]. From U-shaped slots in [6], to L-shaped slots in [7], to fractal shaped slots in [8] have been used. Cho-Kang Hsu et al. [9] had proposed a compact antenna with U-shaped slot for 4G handset applications. The patch antennas are thin and thus support the metal casings of the handheld devices. Three different designs of a U-shaped slot antenna have been studied in [10]. Optimum values of the patch can be observed from the results. In [11], a wide-band patch antenna working in S band is designed using E-shaped patch antenna. In [4], design of an optimized dual frequency patch antenna for C band focusing on 5 GHz and 8 GHz frequency band has been presented. Patch antennas have also been designed for the operation in VHF/UHF bands. Hatam Zaghiran Bavi et al. [12] proposed a new type of the quad ring patch antenna that showed a gain of 10 dB and above. Cutting of slots/slits is one of the basic techniques being used. The fractal shapes have been used to minimize the size and increase the number of operating frequencies of an antenna. In [13], F shaped fractal antenna structure has been used whereas in [8] T-shaped fractal microstrip antenna has been designed for wireless networks. While discussing fractal shapes, Minkowski is the most known fractal shape used. In [14], the antenna has been designed using Minkowski fractal patch for 5.8 GHz applications. A Π-shape microstrip antenna design for Wi-Fi, WiMAX and biomedical applications at 2.45 GHz has been given in [15]. The overall performance, such as size, gain, directivity and efficiency of the antenna depends on the selection of the substrate material as well as on the design procedure [16]. Further, antenna arrays using microstrip patch antennas have been designed [17]. Yazi Cao et al. [18] presented a compact antenna for multiband operation formed by two open-ended slots. A T-shaped slot and an E-shaped slot have been cut at the edge of the ground plane. The antenna could generate five resonant modes which could be controlled almost independently by the five respective monopole slots of different lengths. In this paper, a cross-shaped slot microstrip patch antenna has been proposed for hotspot applications.

II. ANTENNA DESIGN

The proposed antenna basically consists of 3 layers: the ground plane, the substrate and the patch plane. The dimensions of the antenna are 42 mm x 50 mm. FR4 epoxy with dielectric constant equal to 4.4 and thickness equal to 3.2 mm is used as the substrate. A coaxial probe is used as the feed to the antenna. The patch sides are calculated corresponding to the values of the operating frequency and properties of the substrate. The width of the patch is given as:

$$W = \frac{c}{2f0\sqrt{\frac{(\varepsilon r+1)}{2}}}$$

where c is the velocity of light, f_0 is the resonant frequency and ε_r is the relative permittivity of the substrate. The length of the patch is given as:

$$L = \frac{c}{2f0\sqrt{\varepsilon eff}} - 0.824h\left(\frac{(\varepsilon eff+0.3)(\frac{W}{h}+0.264)}{(\varepsilon eff-0.258)(\frac{W}{h}+0.8)}\right)$$

where ε_{eff} is equal to

$$\frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[\frac{1}{\sqrt{1+12\,(\frac{h}{W})}}\right]$$

and c is the velocity of light, f_0 is the resonant frequency, ε_r is the relative permittivity of the substrate, h is the thickness of the substrate and W is the calculated width. The antenna is designed using High Frequency Structural Simulator (HFSS). One side of the substrate is the ground plane and the opposite side is the patch. Coaxial feeding technique is used. The outer conductor of the SMA connector is shorted to ground plane and the inner conductor goes to the patch passing through the substrate. The position of the patch and the feed are optimized for the resonant frequencies. Now, two rectangular slots are cut from the patch. Both the size and position of the slots have also been optimized. The final design of the proposed antenna is as shown in Fig. 1.

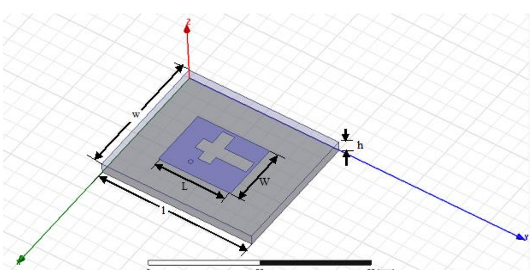

Fig.1 Antenna Specifications.

Table I. shows the dimensions of the antenna specified in Fig.

Table I. Antenna Dimensions.

Parameter	Dimension
h	3.2 mm
W	19 mm
L	24 mm
w	42 mm
l	50 mm

The antenna has been constructed according to the stated dimensions. The specifications of the patch are shown in Fig. 2.

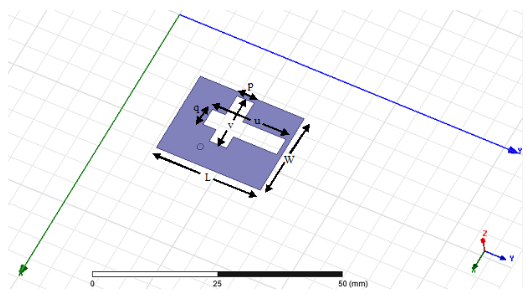

Fig. 2 Patch Specifications.

Initially, the patch and the feed positions are optimized. Slots are then cut. The size and position of the slots have been varied to get the optimum values. Dimensions of the patch are depicted in Table II.

Table II. Patch Dimensions.

Parameter	Dimension
p	4 mm
q	4 mm
u	17 mm
v	12 mm

III. SIMULATIONS AND ANALYSIS

The graph plotted between the S_{11} parameter and the frequency depicts the return losses at the resonant frequencies of the designed patch antenna. It can be seen from Fig. 3, that though the return loss is not good at 2.6 GHz but it is fairly well at 5.5 GHz.

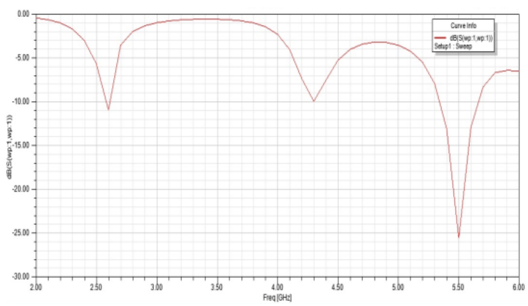

Fig. 3 Return Loss.

An infinite sphere is now inserted for the far field analysis of the antenna. Results are plotted for two different frequencies: 2.5 GHz and 5.8 GHz. Fig. 4(a) and 4(b) show the total gain in dB at 2.5 GHz and 5.8 GHz, respectively.

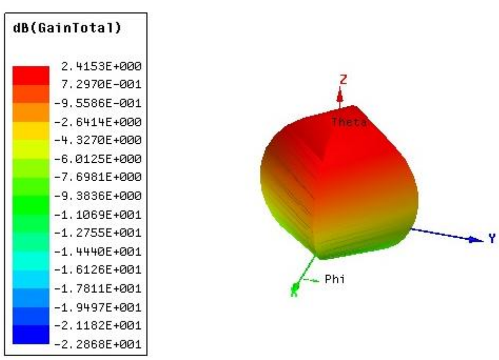

Fig. 4(a) Total Gain (in dB) at 2.5 GHz.

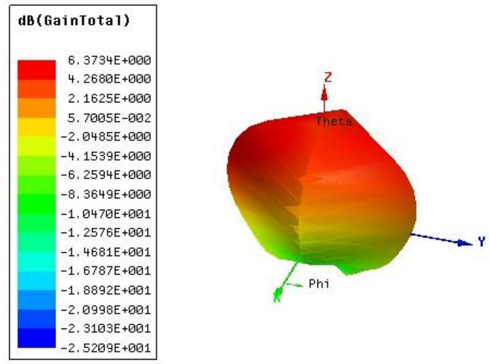

Fig. 4(b) Total Gain (in dB) at 5.8 GHz.

Similarly, the radiation patterns at both the frequencies are plotted. Fig. 5(a) and 5(b) depict the radiation pattern of the antenna at 2.5 GHz and 5.8 GHz, respectively.

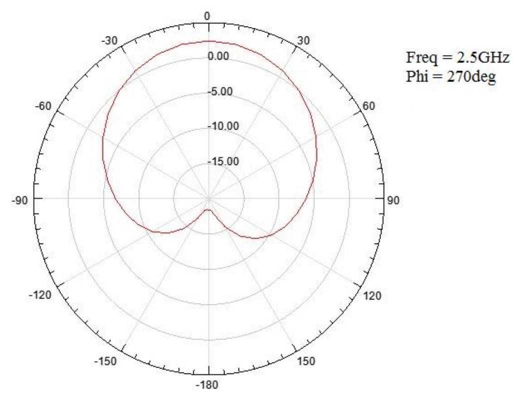

Fig. 5(a) Radiation Pattern at 2.5 GHz.

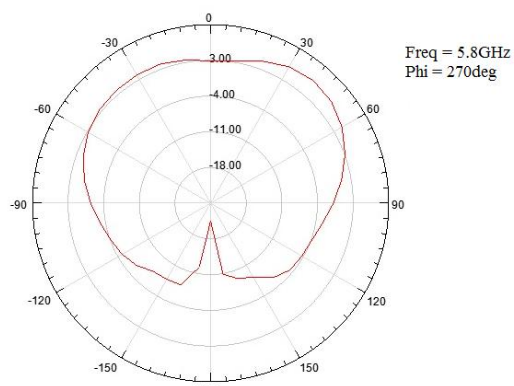

Fig. 5(b) Radiation Pattern at 5.8 GHz.

The directivity of the antenna is plotted for the operating frequency and is shown in Fig. 6.

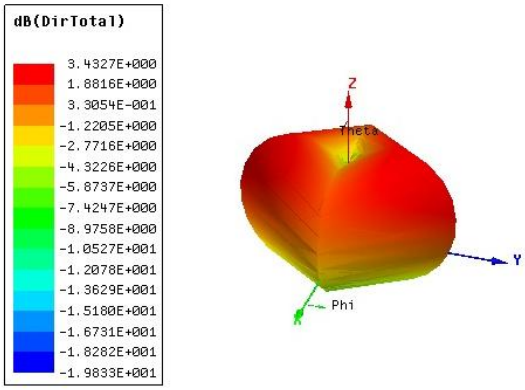

Fig. 6 Directivity of the Antenna.

IV. CONCLUSION

A compact cross-slot microstrip patch antenna has been designed. The design has been simulated for the frequency range of 2 GHz to 6 GHz. Far field analysis has been done. The gain is found to be equal to 2.415 dB at 2.5 GHz and 6.373 dB at 5.8 GHz. The performance of this antenna can further be improved using a frequency selective surface. Thus, this design may find application for hotspot frequencies.

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