Wideband slotted rectangular Microstrip patch antenna for L-band wireless communication

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Abstract

A novel design of wide band planar Microstrip antenna is presented in this paper. A rectangular Microstrip antenna is designed for resonant frequency of 1.5 GHz.The slots are introduced around all the four sides of patch and inner side so that the patch resembles 'swastika'.It is an equilateralcross with four arms bent at 90^0 resulting in 90 degrees rotational symmetry.The slots exhibit diagonal symmetry which results in enhanced bandwidth.Simple line feeding method is used. The antenna operates in the selected range of L-band and the return loss is lower than 10 dB in 1.1-1.6 GHz range(500MHz). The radiation pattern of a proposed antenna is almost omnidirectional with unidirectional single beam at the center.

Keywords: *Planar antenna, Micro strip antenna(MSA), Slots, return loss, L-band, omnidirectional.*

1. Introduction

In recent years Microstrip antennas are becoming increasingly useful because of their inherent advantages. The patch antennas are of low cost, small size, light weight and planar structure [1]. Such antennas are compatible with IC's as they can be easily printed directly on to a circuit board. Because of their planar structure, patch antennas can be mounted on the surfaces of Laptop, aircraft, spacecraft, car etc. However, they suffer from disadvantages like narrow band, low gain, and low efficiency.

Efforts are on to improve the radiation parameters of patch antenna by using several techniques. One of the methods to improve the bandwidth is to introduce slots or slits in thenormal patch antennas[2],[3]. In this paper a rectangular patch is designed for a resonant frequency of 1.5GHz. Slots are introduced around all the foursides and inside the rectangular patch as a result the patch antenna resembles'Swastika' shape. It is simulated using IE3D tool. In this paper section-2 describes patch antenna basics; section-3 covers the design of rectangular patch antenna; Section-4 details about the simulation results and graphs. Finally, results and improvements are discussed in conclusion section-5.

2. Basics of Patch antennas

A patch antenna is a resonant antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a printed circuit board with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is also possible.

2.1 Inset fed rectangular patch antenna

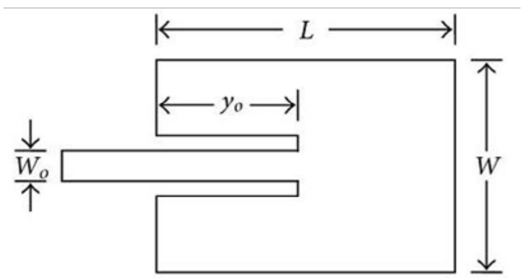

Fig. 1 Inset fed patch antenna

A rectangular patch antenna is a simple line fed antenna with width,W and length,L. Different types of feeding are Line feed, Coaxial feed, Aperture feed and Proximity feed. Suitable feeding method can be used for a particular type of antenna. Inset feed provides adjustable input impedance for matching[5].

2.2 Methods of analysis

The popular methods of analysis are:

Transmission line model: It issimple, easiest of all and gives more physical insight but less accurate.However, it is more suitable for simple structures.

Cavity model: This method is comparatively moreaccurate but complex to analyze. It is used for moderately complex structures.

Full-wave model: Full-wave method is more complex but highly accurate and versatile. Therefore, it can be applied to all types of antenna structures.

3.Antenna design

Initially, line fed rectangular patch antenna is designed for a resonant frequency of 1.5GHz with FR4 as a substrate havingdielectric constant of 4.4. The thickness of substrate is 1.6mm. The design equations of Transmission line model are used for designing simple patch. The design parameters are listed in the Table 1.

3.1 Design parameters

Table 1: Design parameters

Sl. No.	DesignParameters	Parameter values of Designed Patch
1	Operating Frequency (f_o)	1.5 GHz
2	Dielectric Constant of Substrate FR4 ($\mathcal{E}_r$)	4.4
3	Loss Tangent	0.0012
4	Thickness of Substrate (h)	1.60 mm
5	Width of Ground Plane (W_g)	72.40 mm
6	Length of Ground Plane (L_g)	87.12 mm
7	Width of Patch (W)	62.80 mm
8	Length of Patch (L)	77.52 mm

3.2 Design constraints

1.Thickness of the substrate is in the range $0.003\lambda_0 \leq h \leq 0.05\lambda_0$.
2. Thickness of the metallic patch is t<< $\lambda_{0.}$
3. Length of a recatngular patch is $\lambda_{0/3}$< L <$\lambda_{0/2.}$
4. The range of dielectric constant of a substrate is $2.2\leq \varepsilon_r \leq 12$

3.3 Design Equations

The resonant frequency of a patch Antenna is

$$f_0 = \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \ \varepsilon_r \ \mu_0}} \quad (1)$$

Calculation of the Width (*W*):

The width of the Microstrip patch antenna is given by the equation

$$W = \frac{c}{2f\sqrt{(\varepsilon_r + 1)/2}} \quad (2)$$

Effective dielectric constant (**ε_{eff}**):The fields at the edges of the patch undergo fringing and it depends upon the ratio L/h. Since some of the waves travel in the substrate and some in air an effective dielectric constant is introduced to account for fringing and wave propagation in the line[1]. Hence, effective dielectric constant is

$$\varepsilon_{reff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}[1 + 12\frac{h}{w}]^{-\frac{1}{2}} \quad (3)$$

Effective length (L_{eff}): Due to fringing effects, electrically the patch of microstrip antenna looks greater than its physical dimensions. The effective length of the patch is

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (4)$$

Length extension (ΔL):

$$\frac{\Delta L}{h} = 0.412 \frac{(\varepsilon_{reff}+0.300)\left\{\frac{W}{h}+0.262\right\}}{(\varepsilon_{reff}-0.258)\left\{\frac{W}{h}+0.813\right\}} \qquad (5)$$

Actual length of patch (L):

$$L = L_{eff} - 2\Delta L$$

For a resonant frequency of 1.5 GHz,double sided copper clad board with FR4 as a substrate is considered.First, thewidth of patch antenna is calculated by using equation (2). The effective dielctric constant, effective length and length extension are determined from equations (3),(4) and (5) respectively. Finally, actual length is calculated using equation (6). The feeding line of 50Ω is connected to one of the arms as shown in Fig.3.

3.4 Introduction of Slots

The bandwidth enhancement or multiple resonances can be achieved by introducing reactive loading through shaped slot, notch, cuts or post in the patch antennas[4].In the two sided copper clad board, the upper and lower layers are made of copper material. The middle layer is the dielectic material FR4 which forms thesubstrate as shown in Fig.2. The antenna patch pattern is developed on the upper layer as per the design and lower layer is kept intact which acts as a ground plane.

Fig.2. Layers of two sided copper clad board.

The slots are introduced in the outer sides and inside of the patch as shown in Fig.3. These slots on the patch provide diogonal symmetry which guarrantees the increased bandwidth.

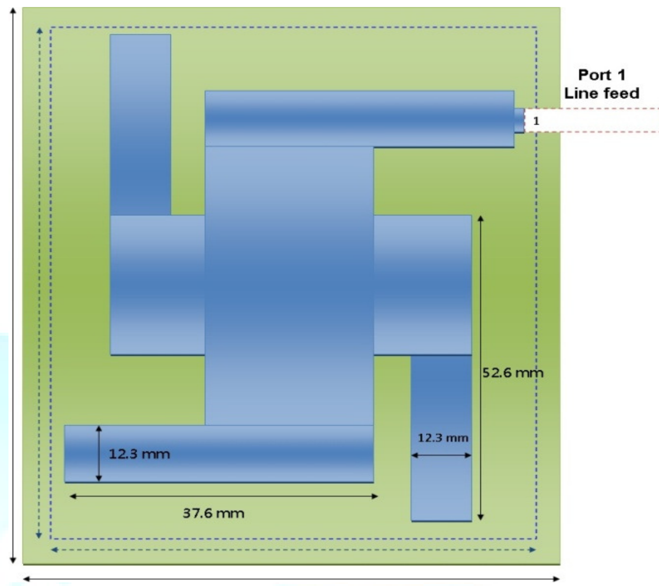

Fig.3.Slotted rectangular patch antenna

4. Simulation

The designed antenna is simulated by IE3D software tool.IE3D is a user friendly tool through which plotting of radiation pattern, return loss graph, current distribution can be easily achieved. Itis the most versatile , accurate and efficient tool[8].First, the basic parameters such as dielectric constant of layers, units and layout dimensions and metal types required for simulationofpatch antenna are defined[8].Then antenna layout is drawn as per the designed dimensions. By following various steps of IE3D theslotted patch antenna is simulated successfully. The reurn loss graph and radiation pattern are plotted.

The return loss graph shown in Fig.4 indicates that operating frequency range is increased compared to that of normal patch antenna which resonates at single frequency. The operating frequency range is 500 MHz in which the return loss is below -10 dB. The minimum return loss of -29 dB is achieved at 1.5 GHz frequency. The radiation pattern of the a slotted patch antenna shown in Fig.5 is not only omnidirectional but also have good dirctivity.

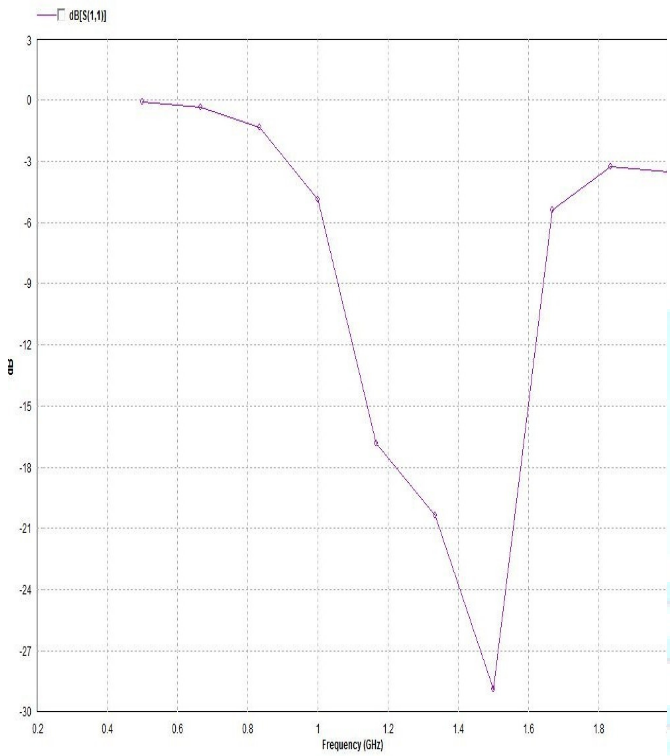

Fig.4.Return Loss(S_{11})

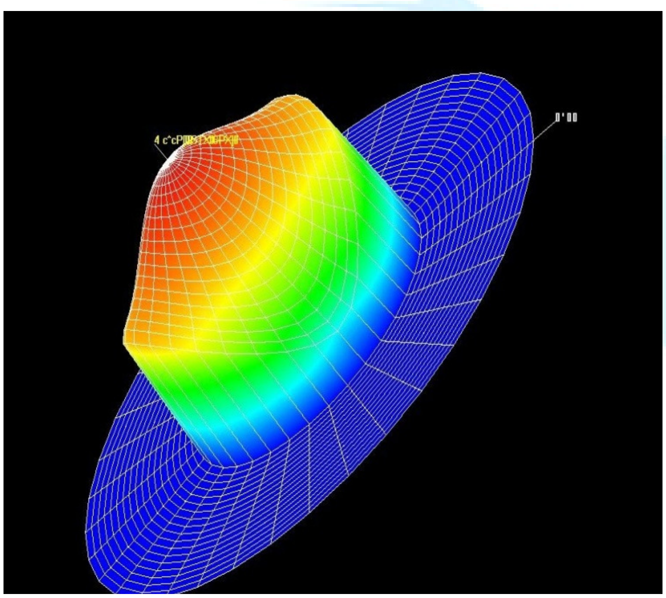

Fig. 5. Radiation Pattern of a slotted patch antenna

5. Conclusions

The Slotted patch antenna proposed in this paperhas improvedradiation characteristics compared to normal one. The designof rectangular slotted patch for L- band (1-2 GHz) is successfully simulated with return loss of -29 dB at 1.5GHz. Thus, relatively good impedance matching is achieved. It is observed that proposed method enhances the bandwidthup to 500MHz over which the return lossis below -10 dB. It is because of diagonal slot symmetry,asexhibitedby other complementary symmetrical slot patch antenna. The radiation pattern is not only omnidirectional but also has main beam with good directivity.The 'line feed' technique makes the design simple and easy to fabricate. However, it is difficult to use inset line feeding as the arms' width is small.

References

[1] C. A. Balanis, Antenna Theory, Wiley India: Third edition,2011.

[2] Abdel-Fattah and Samir F.Mahmoud,"A Widely Tunable Compact Patch Antenna ", IEEE Antenna and Wireless Letters, Vol. 7, No. 1536-1225, 2008, pp40-42.

[3] Chun-I Lin and Kin-Lu Wong, "Printed Monopole Slot Antenna for Internal Multiband Phone Antenna", IEEE Transactions on antenna and propagation, Vol.55, No.12, Dec.2007, pp 3690-3697.

[4] DebatoshGuha "Broad band design of Microstrip antennas: Recent Trends and Developments" Mechanics, automatic Control and Robotics, Vol.3, No.15, 2003, pp 1083-1088.

[5]Warren L. Stutzman, Gary A.Thiele, Antenna Theory and Design, Wiley India: Second edition,2012.

[6] S.Gao and Sambell, "A simple Broadband printed antenna",Progress in Electromagnetic research,PIER 60,pp119-130 UK, 2006.

[7]J.R James and P.S Hall , Handbook of Microstrip Antennas, Vol.1, Peter Peregrinus Ltd. London, United Kingdom,2000.

[8] Nader Behdad "Simulation of 2.4 GHz Anteena using IE3D" EEL 6463,Spring, 2007.