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Dual band , Dual slot Microstrip antenna for ISM band

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Abstract

Abstract—*various iterations have been performed on the basic micro strip patch antenna structure and have been designed for high-speed wireless local area network ISM band (2.4GHZ). In some of the iterations Slots are incorporated to perturb the surface current path, introducing local inductive effect that is responsible for the excitation of the second resonant mode. A substrate of low dielectric constant is selected to obtain a compact radiating structure that meets the demanding bandwidth specification*

Index Terms- ***VSWR, return loss, current distribution, slots, dual band***

1. Introduction

Wireless local area networks (WLAN) are widely used worldwide. The IEEE 802.11b and 802.11g standards utilize the 2.4-GHz ISM band. The frequency band is license-free, hence the WLAN equipment will suffer interference from microwave ovens, cordless phone, Bluetooth devices and other appliances use same band. Micro strip antenna is the ideal choice for such an application due to its low-profile, lightweight, low-cost and ease of integration with microwave circuits. However, standard rectangular micro strip patch antenna has the drawback of narrow bandwidth. Enhancement of the performance to cover the demanding bandwidth is necessary. The bandwidth of micro strip antenna may be increased using air substrate [1]. However, dielectric substrate must be used if compact antenna size is required [2]. A few approaches can be applied to improve the micro strip antenna bandwidth. These include increasing the substrate thickness, introducing parasitic element either in co-planar or stack configuration, and modifying the shape of a common radiator patch by incorporating slots. The last approach is particularly attractive because it can provide excellent bandwidth improvement and maintain a single-layer radiating structure to preserve the antenna's thin profile characteristic. The successful examples include E-shaped patch antennas [3-7], U-slot patch antennas [8], and V-slot patch antennas [9].

1.1. Dual Band Co-axial feed

The antenna geometry for dual band is shown in Fig.1 First, a rectangular microstrip patch antenna is designed based on the standard design procedure to determine the length (L) and width (W) for resonant frequency at 2.4 GHz.

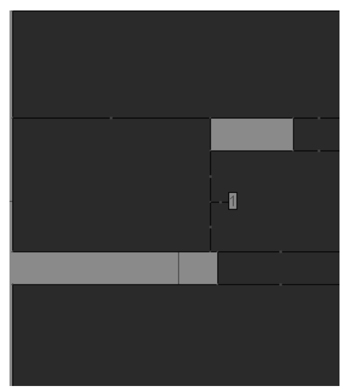

Fig.1. A dual slot loaded patch antenna

Two parallel slots are incorporated to perturb the surface current path, introducing local inductive effect that is responsible for the excitation of a second resonant mode. The slot length (Ls), slot width (Wt) of the antenna control the frequency of the second resonant mode and the achievable bandwidth.

The Єr can be chosen close to unity to obtain broader bandwidth. The expression for approximately calculating the % age bandwidth of the RMSA in terms of patch dimension and substrate parameter is given by [10],

$$\%B.W = Ah\frac{\sqrt{W}}{\lambda 0\sqrt{\varepsilon r * L}} \qquad \text{eq.1}$$

Where W and L are the width and length of RMSA. However W should be taken less than λ to avoid excitation of higher order modes .Another simplified relation for quick calculation of BW for VSWR=2 of

MSA operating at frequency ‘f’ in GHz, with ‘h’ expressed in cms is given by

$$B.W = 50h(f \wedge 2) \qquad \text{eq.2}$$

The minimum quality factor is given by

$$Q\min = \frac{1+3(KoR)\wedge 2}{(KoR)\wedge 3*[1+(KoR)\wedge 2]} \qquad \text{eq.3}$$

The Q_{min} value guarantees maximum radiation efficiency. In the eq.3 $Ko = \frac{2*\Pi}{\lambda o}$ and ‘R’ is the minimum sphere radius which completely encloses the antenna. The antenna volume is proportional to the bandwidth .The technique to increase the bandwidth and to decrease the antenna dimension can be employed in combined way or individually also. The use of high dielectric constant results in poor efficiency due to high loss and surface wave excitation.

1.2 Parametric Study

A substrate with dielectric permittivity of 2.4 and thickness of 1.58 mm is selected to obtain compact radiation structure.The dimensions of dual band rectangular microstrip antenna having two slots are listed below in millimetres.

TABLE.1

Parameter	Design value (mm)
Length of patch	39.6
Width of patch	46.9
Length of slot 1	10
Width of slot 1	4
Length of slot 2	27
Width of slot 2	4

1.3 Simulation Results of dual band antenna

The Smith Chart for Rectangular Patch Antenna is shown in fig . The Impedance plot is well within the unity VSWR circle for dual frequency.

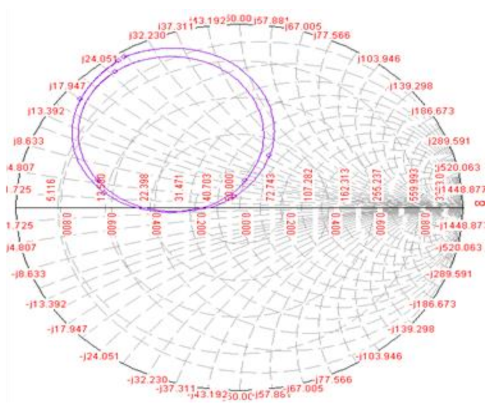

Fig1a. Smith Chart for Rectangular Patch Antenna

The fig.1b shows the graph of frequency verses VSWR it shows that the antenna has VSWR less than 2. The bandwidth of an antenna is usually defined by the acceptable standing wave ratio (SWR) value over the concerned frequency range. It is a very popular parameter for determining the BW of a particular antenna configuration (1≤ VSWR ≤ 2). The VSWR is <1 at a frequency of 2.4GHz and <1.5 At freq 2.74GHz.

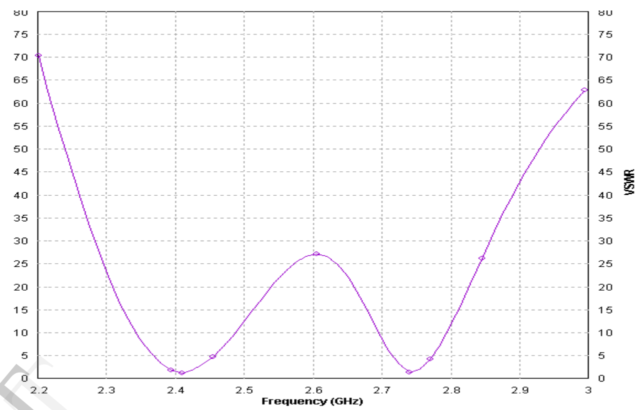

Fig.1b The plot of VSWR using *IE3D*

There is a point where the impedance is 50 Ω somewhere along the "resonant length" (x) axis of the element. The fig.1cshows the graph of impedance vs. frequency for rectangular patch antenna having Impedance is 50Ω at a frequency of 2.74GHz and 55 Ω at 2.4 GHz.

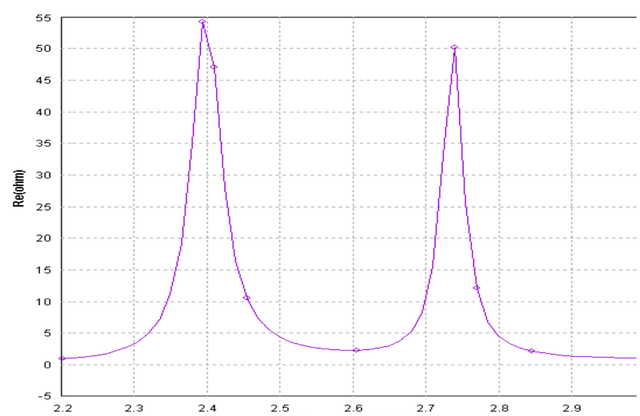

Fig.1c Plot of input impedance

The Fig.1d shows the graph of antenna efficiency vs. frequency for rectangular patch antenna. The antenna efficiency is 85% at frequency of 2.41GHz and 79% at 2.74GHz.

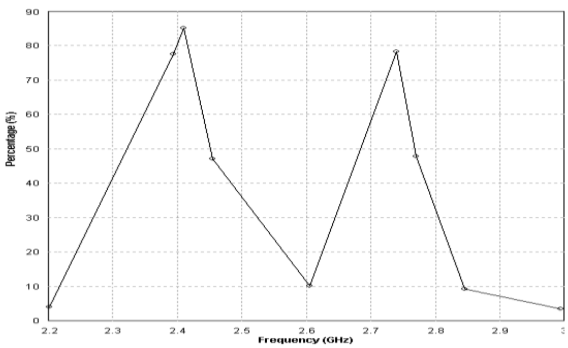

Fig.1d Plot of antenna effeciency

Consider the power density radiated by an isotropic antenna with input power P_0 at a distance R which is given by $S = P_0/4\pi R^2$. An isotropic antenna radiates equally in all directions, and radiated power density S is found by dividing the radiated power by the area of the sphere $4\pi R^2$. An isotropic radiator is considered to be 100% efficient. The graph of radiation efficiency vs. frequency for rectangular patch antenna shown in fig.1d gives radiation efficiency of 87% at frequency of 2.4GHz and 80% at 2.74GHz.

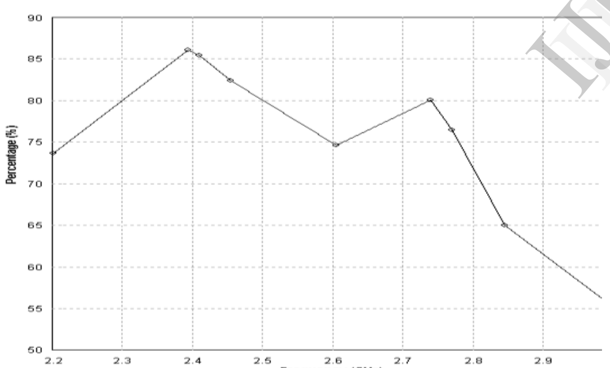

Fig.1e Plot of radiation efficiency

The graph of gain vs. frequency for rectangular patch antenna is shown in the fig.1e. Gain is a measure of the ability of the antenna to direct the input power into radiation in a particular direction and is measured at the peak radiation intensity. The gain is 7dBi at frequency of 2.41GHz and 5.9dbi at 2.75GHz.

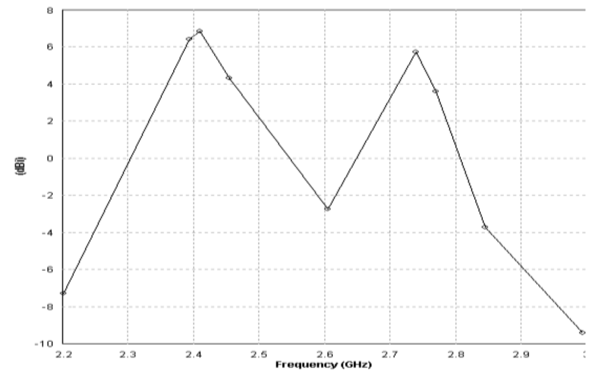

Fig.1f Plot of antenna gain (dbi)

The graph of directivity vs. frequency for rectangular patch antenna is shown in fig.1g. Directivity is a measure of the concentration of radiation in the direction of the maximum. Directivity and gain differ only by the efficiency, but directivity is easily estimated from patterns. The directivity is 7.625dBi at frequency of 2.45GHz and 6.85dbi at 2.75GHz.

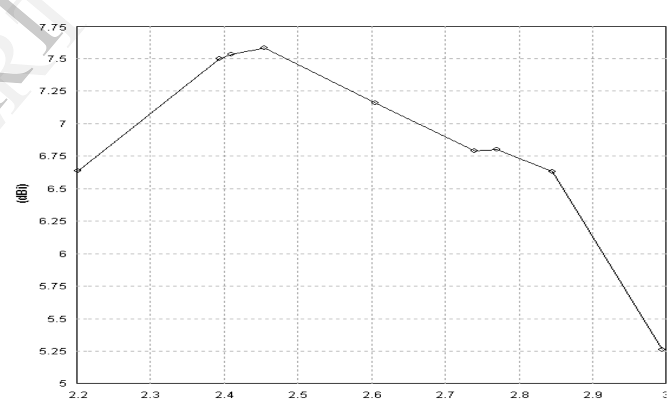

Fig.1g Plot of antenna directivity

The radiation pattern of an antenna is a plot of the far-field radiation properties of an antenna as a function of the spatial co-ordinates which are specified by the elevation angle (θ) and the azimuth angle (φ). More specifically it is a plot of the power radiated from an antenna per unit solid angle which is nothing but the radiation intensity. The 3D Radiation Pattern for Rectangular Patch Antenna is shown in fig.1h.

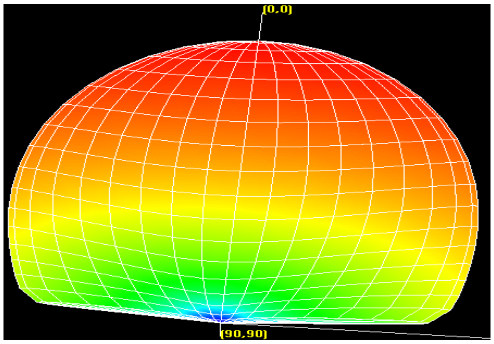

Fig.1h Plot of radiation pattern

2.Dual Band strip line feed

A dual band response from a rectangular microstrip antenna is obtained by introducing two rectangular slots as shown in figure 2. The effectvie dielectric constant for the antenna in figure 2 is 2.4.For the rectangular micorstrip antenna with two slots inside the patch , the simulated dual frequencies were 2.42GHz and 2.75 GHz. Here the first frequency (f1) was governed by the patch mode (which mainly depends on the length of the rectangular patch antenna) and the second frequency (f2) was governed by the slots introduced. While simluating in the *IE3D* software the meshing frequency was kept at 3GHz and the cell per wavelenght which is to be meshed was kept at a value 15.Higher value can increase the simulation time and also decreases the performance of the antenna.

2. EFFECT OF REDUCING THE SLOT DIMENSION AND POSITION

Fig.2. A dual slot with strip line feed

The figure 2 shows the micro strip patch antenna with two parallel slits incorporated to attain a dual band of frequencies. A comprehensive parametric study has been carried out to understand the effects of various dimensional parameters and to optimize the performance of the final design.

The antenna geometry is shown in Fig. 2. The BW is approximately 15% for εr=2.2 and h=.01λ0. The εr can be chosen close to unity to obtain broader bandwidth

The antenna parameters are listed below in millimeters

Parameters	Design values
Length of patch	39.6mm
Width of patch	46.9mm
Length of slot	14.2mm
Width of slot	1.4mm
Inset depth	13.2mm

Achieving impedance matching at both frequencies:- It is achieved by varying the slot width when we increase slot width ,the input impedance change. It is also found that increasing the inset feed length simultaneously reduce the input impedance at both frequency to 50 Ω .The inset feed has slight effect on both resonant frequencies and thus slight tuning is required.

In order for the antenna to operate efficiently, maximum transfer of power must take place between the transmitter and antenna. Maximum power transfer can take place only when the impedance of the antenna matchs with that of transmitter. The VSWR expresses the degree of match .As shown in figure 2d. VSWR=1.8db for the designed antenna .The fig.2b shows the plot of two resonant frequency of the smith chart which depicts that the two resonant frequencies are well inside the VSWR=1 circle.

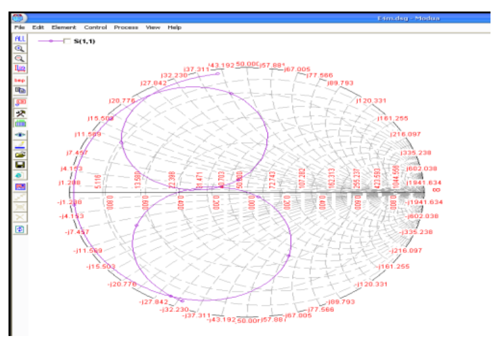

Figure2a Smith chart

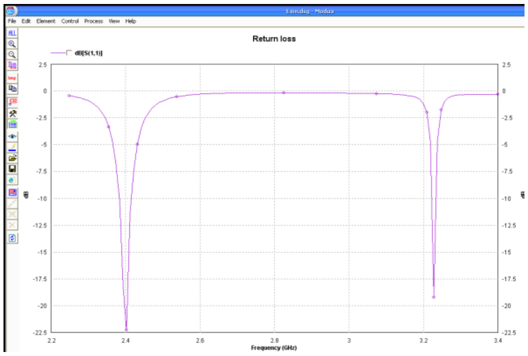

Figure2 b. Return loss

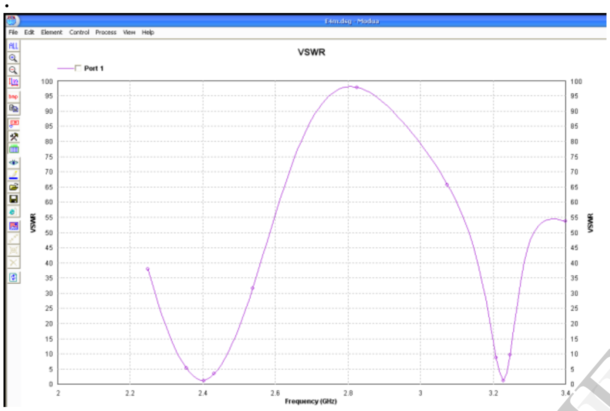

Figure2 c. Voltage standing ratio (VSRW)

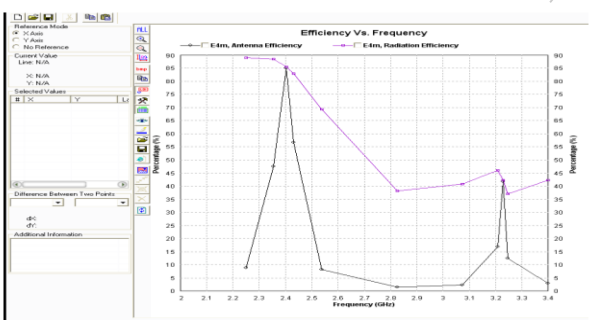

Figure2d. Antenna efficiency and radiation efficiency

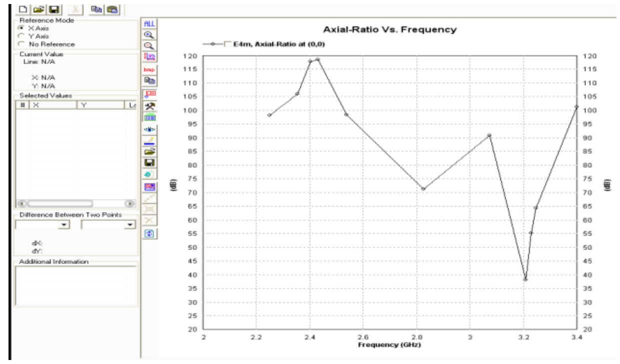

Figure.2 e Axial ratio

The antenna presented in this is basically linear polarized, so for that the axial ratio should be high, ideally infinity.The axial ratio is the ratio of orthogonal components of an E-field.

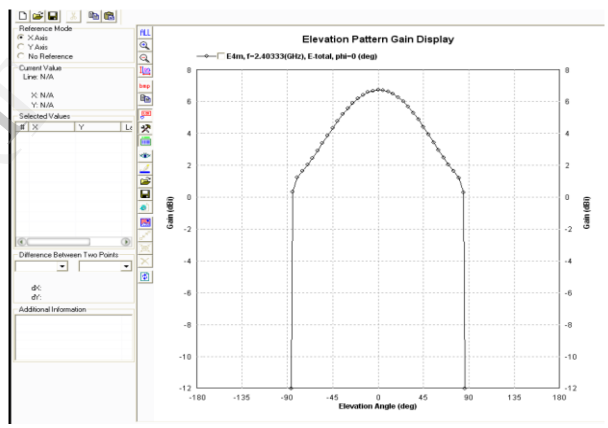

Figure.2 f Gain

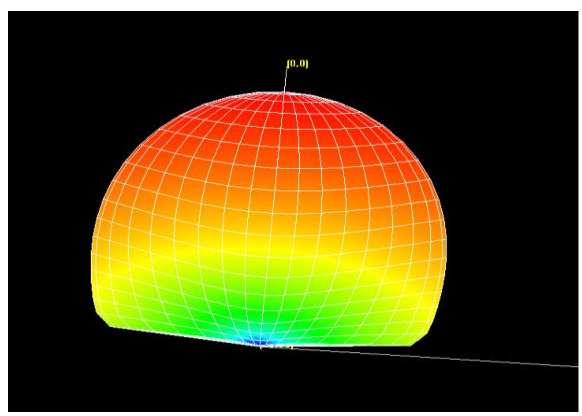

Figure2 g. Radiation pattern

The results of the simulated antenna using IE3D are tabulated below.

Parameters	Resonant frequency (2.40 GHz)	Resonant frequency (3.23 GHz)
Return loss (db)	-22.5	-18.5
VSWR	1.8	1.8
Antenna efficiency	85%	42.3%
Axial ratio	117.5	38
Gain (dbi)	6.7	-3.32

APPLICATIONS

For many applications, the advantages of micro strip antennas far outweigh their limitations. Initially, micro strip antennas found widespread applications in military systems such as missiles, rockets and satellites .Currently, these antennas are being increasingly used in commercial sector, due to the reduced cost of substrate material and mature fabrication technology. With continued research and development and increased usage, micro strip antennas are ultimately accepted to replace conventional antennas for most applications. The present design has an efficiency of 85% and can be used in wireless routers.

Figure2 i. Router

CONCLUSION

A wide band parallel slot micro strip patch antenna has been designed for wireless communication system.. The performance is satisfactory and at the same time the antenna is thin and compact with low dielectric constant substrate material. These features are very important for the portability of wireless communication equipment. It should be noted that the performance of the proposed antenna is not optimized. By varying slot length and width the second resonant frequency can be changed without affecting the resonant frequency of fundamental mode.

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