A TRIPLE RECTANGULAR-SLOTTED MICROSTRIP PATCH ANTENNA FOR WLAN & WIMAX APPLICATIONS

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ABSTRACT

A triple rectangular slotted microstrip patch antenna is designed and investigated with and without slot using CST Software. By using the triple rectangular shaped slot the designed antenna operates at 2.4GHz (ranging from 2.3704 GHz (Gigahertz) to 2.4391 GHz at -10dB return loss) for WLAN (Wireless Local Area Network) and 3.6GHz (ranging from 3.5643 GHz to 3.6548 GHz at -10dB return loss) for WiMAX (Worldwide Interoperability for Microwave Access) applications having a maximum return loss -28.5dB and -25.4dB respectively. For the design of this antenna we have chosen FR-4 (lossy) as substrate having permittivity 4.3. The designed antenna has appreciable values of gain and directivity at both the frequencies. The proposed antenna works on the principle of excitation of the slots at the operating frequencies. The antenna was designed keeping in mind the two major Wireless standards i.e., WLAN and WiMAX bands of frequencies. The proposed triple-rectangular slots are unique in terms of its construction and have appreciable results at the operating frequencies.

KEYWORDS

MSPA, Rectangular slots, Return loss, WLAN, WiMAX

1. INTRODUCTION

Due to the robustness and simplicity of wireless communication, there is a huge demand of MSPA's (Microstrip patch antennas) arises in the communication sector/area. [1] And to fulfill these requirements of wireless communication the MSPA's has become widely/broadly centre of study for the researchers since few decades. Since the evolution of the wireless communication also there is a trend started for the patch antennas to be used for different frequencies with the single antenna. Also in modern era the single antenna is being used by the devices like mobile phone, satellites, war crafts, spacecrafts etc. for the purpose to work on the multiple frequencies for different applications.[2-3] So the researchers are doing hard to make it for such applications with better bandwidth, less cost, high gain, very compact in size.

Micro-strip antennas are very tiny, compact, very low weight and more easily compatible with the devices. It is thoroughly used in handheld wireless gadgets, war-crafts, war-ships and satellites for the communication wirelessly. [4] Although with these suitable features, it also suffers from some drawbacks like small bandwidth, less gain and sometimes unwanted lobe radiations which degrade the performance level of such antennas. The configuration of MSPA (Microstrip Patch Antenna) is obtained by simply deploying a dielectric material followed by a metal under and above as shown below in the fig. The size with respect to its effective features makes it different and most important from other antennas.

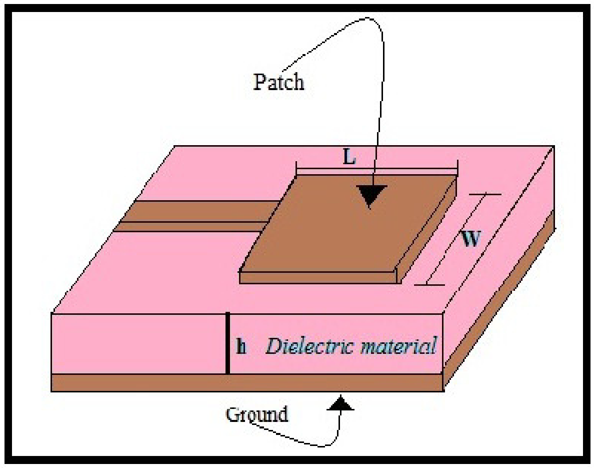

Fig.1. Microstrip patch antenna

From the inception of the patch antenna many more techniques has been used to enhance the antenna's characteristics. To design a multiband patch antenna is trending topic among researchers as it has wide application in the modern world of communication. For the designing of such antennas a much way of configuration are being used by the researchers. By introducing different type of structures (U- slot, L- slot, T- slot, rectangular slot, pi shaped slot etc.) on the patch and the ground. A double meander slot on the patch make a antenna resonate at dual frequency but a triple meander slots gives better return loss than the dual.[5]. The aim of cutting slots on the patch gives a new mode of frequency along with their fundamental band of operation , a half U-slot on the patch introduce a new mode and again a rectangular slot also gives a new mode and by changing geometry of these a triple mode antenna exists.[6]. Over one or two decade back a new geometry called fractal geometry are also introduced for designing of multiband patch antenna. As J.J. Huang , he had used fractal geometry for multiband antenna design and he found many bands between 0.5 GHz to 5 GHz, so this technique is also being frequently used by the researchers. [7]. Stacked patch also have an impact in designing of multi-frequency RMSPA (Rectangular Microstrip Patch Antenna), in this design multi layers of patches and substrate are stacked to one another. Also stacked patch with slots on the patches are used for increasing the gain. [8].

Here we have presented a unique structure of the rectangular patch antenna by inserting triple rectangular slots into the patch to make it radiates at useful multiple frequencies (2.4 GHz and 3.6 GHz). The presented design of the patch antenna is easy to design and fabricate so these may be the major advantage for this designing.

2. ANTENNA DESIGN

For the design of RMSPA (Rectangular Microstrip Patch Antenna), the three parameters are most essential to be chosen first. These are (i) Operational frequency (fo):-It should be chosen according to our need of operation. In our design we have chosen 2.4GHz resonating frequency for WLAN (Wireless Local Area Network) use. (ii) Dielectric permittivity of the substrate (ϵ_r):- More dielectric constant value reduced size of the designed antenna. So FR-4 (lossy) having ϵ_r=4.3, 0.025 as loss tangent and thermal conductivity 0.3 [W/K/m] have been selected for this design. (iii) Substrate height (h) :- Should be minimum so that the final dimension of the antenna should not be bulky. [9] I have selected it 1.6 mm.

2.1 ESSENTIAL CALCULATIONS BY THE FORMULAE.

For the complete dimension of the patch we have chosen some parameters and then calculated it by the formulae given below stepwise.

$$f_0=2.4 \text{ GHz}$$

c=Speed of light (approximately $3.00 \times 10^8\ meter/second$)

$$\epsilon_r=4.3$$

Thickness of the dielectric material (h)=1.6 mm

Step 1:- Width of the patch (W_p):

$$Wp = \frac{c}{2fo\sqrt{2/(\varepsilon r+1)}} \tag{1}$$

Step 2:- Effective dielectric constant (ϵ_{reff}):

$$\epsilon_{reff} = \frac{(\epsilon_r+1)}{2} + \frac{(\epsilon_r-1)}{2}(1+12\frac{h}{Wp})^{-\frac{1}{2}} \tag{2}$$

Step 3:- Effective length (*Le*):

$$Le = \frac{c}{2fo\sqrt{\epsilon_{reff}}} \tag{3}$$

Step4:-Extension in patch length (ΔL):

$$\Delta L = 0.412h\frac{(\epsilon_{reff}+0.3)(\frac{Wp}{h}+0.264)}{(\epsilon_{reff}-0.8)(\frac{Wp}{h}+0.8)} \tag{4}$$

Step 5:- Patch length (*Lp*):

$$Lp = Le - 2\Delta L \tag{5}$$

For the dimension of ground plane and substrate we have taken double the length and width of the patch, or we can also take it by the formulae given below:-

$$Wg = (6h + Wp) \quad and \tag{6}$$

$$Lg= (6h + Lp) \tag{7}$$

Table:1 Parameters and their values for the antenna design.

Parameters	Values in mm
Ground length (Lg)	58.0
Ground width (Wg)	76.0
Substrate length (Ls)	58.0
Substrate width (Ws)	76.0
Patch length (Lp)	29.0
Patch width (Wp)	38.0
Feed-line length (Lf)	29.0
Feed-line width (Wf)	3.317
Slot 1 length (a)	11.0
Slot 2 length (b)	9.0
Slot 3 length (c)	9.8
Metal height (Mt)	0.035
Substrate height (Ht)	1.6
Width of the slots (d)	1.0
Gap between feed-line and patch(e)	2.0

The table given above gives a complete data for the designing of this proposed RMPA. This paper comprises of an antenna substrate as FR-4 (lossy) having dielectric permittivity 4.3, ground and patch material is taken as PEC (Perfect Electric Conductor). Thickness of the ground and the patch material are kept 0.035 mm, we may also choose copper instead of PEC but here it is PEC. The dimensions of the ground plane and substrate are taken as double the length and width of the patch.(i.e. Lg X Wg). There is also an another way of selecting the ground and substrate dimensions by the formulae listed above in eqn. (6) and equation (7) that says the ground and the substrate can be also chosen six times the dielectric height addition with patch width for ground width and similarly six times dielectric height addition with patch length for ground length respectively. For feeding the antenna many techniques are being used mostly microstrip line, aperture coupled, co-axial feed, coplanar wave guide. Microstrip line inset feeding is simple and effective in various matters so this technique has been used for feeding the antenna with a valid impedance matching at 50 ohm. To make the antenna useful for more than one operational frequency multiple slots are cut from the patch . After introducing multiple slots the antenna become resonating at 2.4GHz for WLAN use and 3.6 GHz for WiMAX application. The Table below gives the complete mathematical value of the antenna design.

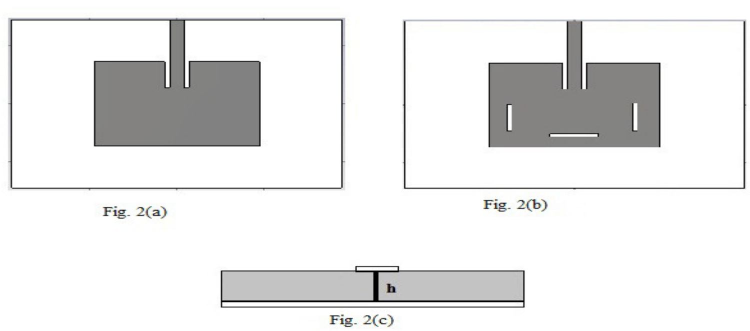

Fig. 2(a) Top view without slot (b).Top view with slot. (c).Side view

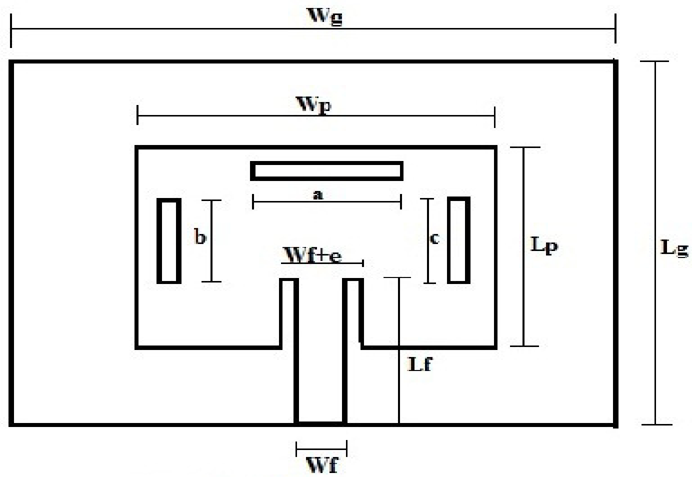

Fig. 2(d)

Fig. 2(d) Detail description of the Patch antenna with complete dimensions

The figure shown above Fig. 2(a) is the top view of the patch antenna before the introduction of slots, Fig. 2(b) is also the top view of the proposed antenna after the cutting of slots and Fig.2(c) describes the side view with the substrate height (**h**) in between the metallic ground layer and the patch layer. Fig. 2(d) describes the complete design parameters with their notations, the value of these parameters is give in Table:1 briefly. The width of all the three slots are taken 1.0 mm and the gap between inserted feed-line and patch is kept 1.0 mm both the sides. The waveguide port is selected for feeding the antenna, dimensions of the waveguide port is calculated through the formula along z axis is given below in equation (8) and (9).

$$Width = 6Wf \tag{8}$$

Where Wf is width of microstrip feed line.

$$Length = mt + 5h \tag{9}$$

Where **mt** is metal thickness and **h** is dielectric height.

3. Results And Discussion

To achieve a specified operational frequency of a patch antenna, the several techniques are being used by the researchers like introducing slots, optimizing dimensions, using EBG (Electromagnetic Band Gap). Here in this paper we have cut three rectangular slots on the patch of the antenna and by using hit and trial method we adjusted the dimensions and positions of the slots to resonates the antenna at a frequency 2.4 GHz for WLAN and 3.6 GHz for WiMAX use .i.e., we make it resonate for dual frequency which are being used for these two purpose. Also we have observed that by cutting the slots on the patch the current distribution on the surface changes and so frequency and impedance matching at that frequency changes. So we have investigated the design by laying different positions and shapes of the three rectangular slots to make the antenna resonate at that frequency which we desire for.

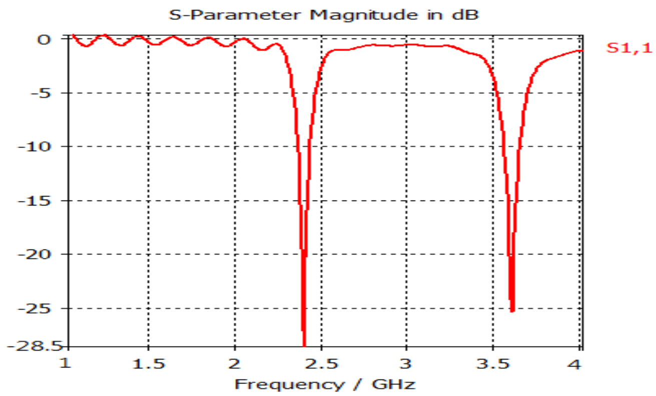

Fig. 3(a) S_{11}-Parameter Magnitude in dB at 2.4 GHz and 3.6 GHz

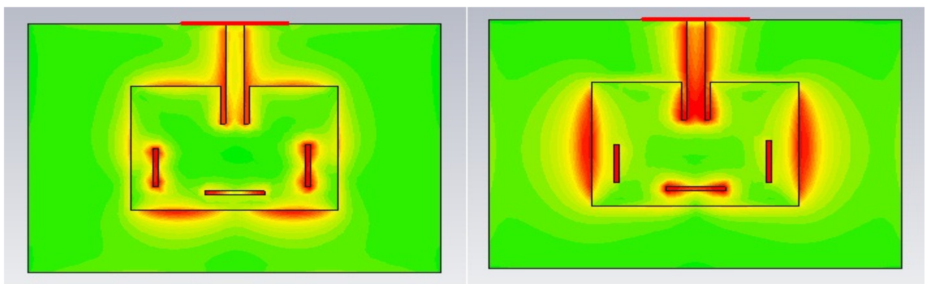

Fig. 3(b) Fig. 3(c)

Fig. 3 (b) Surface current distribution at 3.6 GHz (c) Surface current distribution at 2.4 GHz

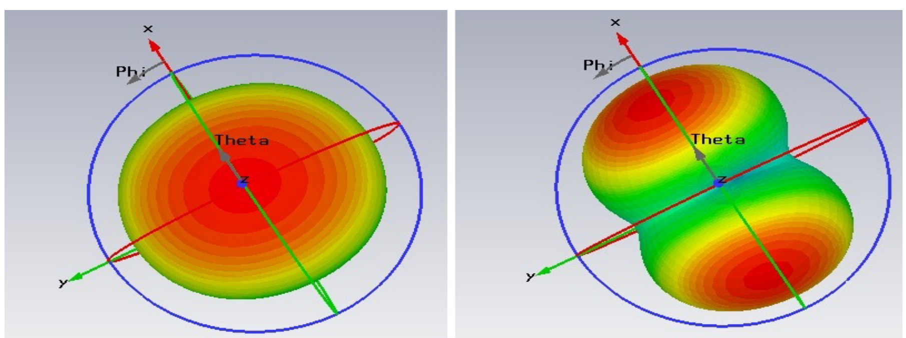

Fig. 3(d) Fig. 3(e)

Fig. 3 (d) 3-D radiation pattern at 2.4 GHz. (e) 3-D radiation pattern at 3.6 GHz.

To check the performance characteristics of a patch antenna we examine the various parameters such as S_{11}-parameter, radiation pattern, gain, directivity and such others. Here we have also examined and represented some few of them given above in the figures. The Fig. 3(a) shows the s-parameter of the proposed antenna and it clearly indicates that two major lobes at 2.4 GHz and 3.6 GHz having an effective return loss 28.5 dB and 25.4dB respectively. Fig. 3(b) and Fig. 3(c) shows surface current distribution at 3.6 GHz and 2.4 GHz respectively with the indication that the slot-1 resonates at 2.4 GHz only, slot-2 and slot-3 resonates at 3.6 GHz only. Fig. 3(d) and Fig. 3(e) shows 3-D radiation pattern, in Fig. 3(d) at 2.4 GHz antenna is resonating as unidirectional while in Fig. 3(e) at 3.6GHz it will be bidirectional.

Table: 2 The gain and directivity of the antenna at operating frequencies.

Operating Frequencies	Application	Gain(dB)	Directivity(dBi)
2.4 GHz	WLAN	3.850	6.987
3.6 GHz	WiMAX	2.947	6.814

The table- 2 shown above gives the values of the gain and directivity of the designed patch antenna at the respective frequencies. These two parameters are very vital for evaluation of an antenna about their performances. Higher the gain at a frequency indicates that the efficiency of the antenna will be higher.

4. CONCLUSION

A Triple rectangular-slotted Microstrip patch antenna has been presented in this research article. The antenna operates at two operating frequencies i.e., 2.4GHz and 3.6 GHz as clearly indicated in the manuscript above. The proposed antenna can find its applications in the WLAN and WiMAX frequency bands for wireless applications. The gain and directivity of the antenna at the WLAN band is 3.850 dB and 6.987 dB respectively, similarly the gain and directivity of the antenna at WiMAX band is 2.947 dB and 6.814 dB. The gain and directivity of the antenna is appreciable at both the operating frequencies. The proposed triple-slotted design can be extended further by enhancing the bandwidth of the antenna, even the gain of the antenna can be enhanced using the Electromagnetic Band Gap structures. The antenna radiates mainly in the desired direction and which becomes double lobes at the WiMAX, the future aim is also at enhancing the directivity in the desired direction.

REFERENCES

[1] S. Dwivedi, S. G. Yadav & A. K. Singh, (2014). "Annular ring embedded l-slot rectangular microstrip patch antenna". In Student's Technology Symposium (TechSym), pp. 372-375. IEEE

[2] M. T. Ali, N. Ramli, M. K .M. Salleh & M. N. Md. Tan (2011). A design of reconfigurable rectangular microstrip slot patch antenna. IEEE International Conference on System Engineering and Technology (ICSET), pp. 111-115.

[3] B. R. Piper & M. E. Bialkowski, (2004). "Electromagnetic modeling on conformal wideband and multi-band patch antennas by bridging a solid object modeler with MoM software". Antenna and Propagation Magazine, Vol. 46(5), pp. 42-45.

[4] Q. Rao, T. A. Denidi & R. H. Johnston, (2005). "A new aperture coupled microstrip slot antenna." IEEE Transactions on Antenna and Propagation. Vol. 53(9), pp. 2818-2826.

[5] M. Z. A. Abd Aziz, Z. Zakaria, M. N. Husain, N. A. Zainuddin, M. A. Othman & B. H. Ahmad, (2013). " Investigation of dual and triple meander slot to microstrip patch antenna". IEEE 13th Conference on Microwave Techniques COMITE. pp. 36-39.

[6] R. Pandey & Dr. D. K. Vishwakarma, (2015). " A meander line uniplanar EBG based multiband antenna using defected ground plane for WLAN and WiMAX applications." IEEE International Microwave and RF Conference (IMaRC). Pp. 64-67.

[7] J. J. Huang, F. Q. Shan & J. Z. She, (2006). " A novel multi band and broadband fractal patch antenna." Progress In Electromagnetics Research Symposium. Vol. 2(1), pp. 57-59.

[8] H. Nornikman, F. Malek, N. Saudin, M. Md. Shukor, B. H. Ahmad & N. A. Oathman, (2013). "Design of rectangular stacked patch antenna with four L shaped slots CPW-Fed for WiMAX application". IEEE 3rd International Conference on Instrumentation, Communications, Information Technology, and Biomedical Engineering (ICICI-BME), pp. 39-43.

[9] C. Balanis (2005). "Antenna Theory and Design". John Wiley and Sons Inc.

[10] K.F. Lee, S. L. S. Yang & A. Ahmad (2008). " Dual and multiband U-slot patch antennas". IEEE Antenna and wireless propagation letters. Vol. 7, pp. 645-647.

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