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Design of Multiband Microstrip Patch antenna with I-shape slot for wireless applications

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Abstract: *In this paper a new structure of multiband micro strip patch antenna is designed and analysed. The proposed micro strip patch antenna is designed with H-shaped slot. The proposed micro strip patch antenna with H-shape slot is results in dual frequency band Ist band at 2.42Ghz and another at 3.59Ghz. The proposed patch antenna is further modified by introducing double I shaped slots. The modified antenna results in three frequency bands Ist at 2.44Ghz, IInd at 3.54Ghz and IIIrd at 5.37Ghz. Also the radiation characteristics, such as, return loss, VSWR, input impedance, radiation patterns and the surface current densities have been introduced and discussed. The proposed and modified micro strip patch antenna is designed on FR4 substrate that having dielectric constant 4.4. of thickness 1.50mm. Design results are obtained by a HFSS (High Frequency Structure Simulator) which is used for simulating microwave passive components.*

Keywords*:* Microstrip, slot, return loss, VSWR, dielectric, radiation pattern.

INTRODUCTION

Antennas play a very important role in the field of wireless communications. Different types of antennas are Parabolic Reflectors, Patch Antennas, Slot Antennas, and Folded Dipole Antennas. All type of antenna is good in their own properties and usage. Hence antennas are almost everything in the wireless communication without which the world could have not reached at this advance age of technology

In today's world the role of microstrip patch antennas is a very significant in the field of wireless communication systems. Construction of a microstrip patch antenna [1] is very simple using a conventional Microstrip fabrication technique. Microstrip patch antennas with rectangular and circular patch are most commonly used antnnas. These patch antennas are used as simple and for the widest and most demanding applications. Dual characteristics, circular polarizations, dual frequency operation, frequency agility, broad band width, feed line flexibility, beam scanning can be easily obtained from these patch antennas. The Microstrip antennas are very popular based on their applications. This antenna has some Merits and De-merits as any other. The merits of these antennas have some similarities as of the conventional microwave antennas, as these cover a broader range of frequency from 100 MHz to 100 GHz, same is the case with these Microstrip antennas. Some merits of these Microstrip antennas are Low weight, low volume and thin profile configurations which can be made conformal [1]. Low fabrication cost, readily available to mass production. Linear and circular polarizations are possible. Easily integrated with microwave integrated circuits. Capable of dual and triple frequency operations. Feed lines and matching network can be fabricated simultaneously. These are widely used in the handheld devices (wireless) such as pager, mobile phones, etc.

A number of microstrip patch antennas with multiband property have been proposed, and various techniques have been used to achieve the multiband operation [2][3]. The mainly used methods are etching slots and slits on the patch or on the ground plane, for

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examples S-shaped slot [2], U-shaped slot [4], C-shaped slot [5]etc.

Most of the previous researches have been adapted for multi-band design; few researches have been focused on dual-bands design. Dual-bands antennas designs have been explained in the papers [6]–[8].In these above papers the dual- band have been achieved by adding the proper slits in the near of radiating patch element and the ground plane, by the inserting of slit, the desired two rejected bands have been obtained.

In this paper a multiband microstrip patch antenna is proposed. This proposed microstrip antenna is designed on a FR4 substrate which is having dielectric constant of 4.4. On the substrate a rectangular shape patch is introduced. A H- shaped slot on the top of radiating patch and by using the probe feed line the dual bands are achieved. For increasing the resonance frequency, new double I-shaped slots are used on the radiating patch and the bandwidth of antenna is also increased by using these slots. However, these antennas are not fulfilling the complete requirement of multiband operation for wireless technology. These antennas are small in size and compact. These structures are designed and simulated with microstrip technology and suitable for multiband wireless communication.

The paper is organized as follows. In Section 2, basic design of proposed microstrip patch antenna is described. In Section 3, the modified structure of microstrip patch is presented for tetra-band operation. In Section 4, the simulated results of proposed dual band and tri-band antenna design are presented and compared. Finally, the paper is concluded in Section 5.

DESIGN AND MODELING

This section, we will introduce the design of our antenna. First the three essential parameters for the design of a rectangular Microstrip Patch Antenna are:

• Frequency of operation (f_o): The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for design is 2.4 GHz.

• Dielectric constant of the substrate (ε_r): The dielectric the dielectric substrate is selected as 1.6 mm. material selected for design is glass epoxy which has a dielectric constant of 4.4.

• Height of dielectric substrate (h): For the microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the conventional patch antenna is selected as 1.6mm.

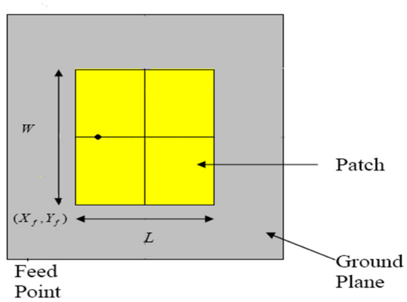

Figure 1: Rectangular microstrip antenna

The initial calculation starts from finding the width of the patch which is given as:

Step 1: Calculation of the width of Patch (W)-

The width of the Microstrip patch antenna is given as

$$W = \frac{c}{2 f_o \sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

For f_o=2.4GHz, ε_r=4.4

We get W=38.22 mm.

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Step 2: Calculation of effective dielectric const-

Fringing makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant is introduced, given as:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

We get ε_{reff}=3.99

Step 3: Calculation of Length of Patch (L)-

The effective length due to fringing is given as:

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}}$$

For ε_{reff}=3.99, f_o=2.4GHz

We get L_{eff} =30.25 mm

Step 4: Calculation of ΔL -

Due to fringing the dimension of the patch as increased by ΔL on both the sides, given by:

$$\Delta L = 0.412h \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)}$$

For W=36.4mm, h, =1.53mm, εreff=3.99

We get ΔL=0.70mm

Hence the length the of the patch is: L= Leff-2ΔL=28.4 mm

Step 5: Calculation of Substrate dimension-

For this design this substrate dimension would be

Ls=L+2*6h

Ws=W+2*6h

Ls = 2*6h + L = 2*6(1.6) + 39 = 59mm

Ws = 2*6h + W = 2*6(1.6) + 30 = 50 mm

Step 6: Calculation of feed length-

For this feed would be given-

lam/4*sqrt(4.4) distance.i.e 14.5mm.

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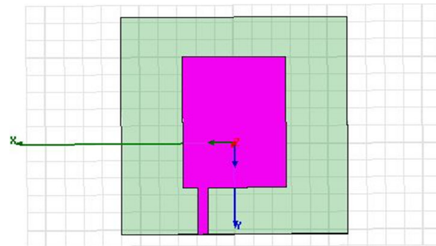

Figure 2: HFSS model of Rectangular microstrip patch antenna

After designing a simple rectangular microstrip patch antenna for 2.4 Ghz frequency band, a single H- shaped slot is inserted on the radiating patch. And for the proposed antenna a dual frequency band is achieved. The Hfss model for the I-shape slot is as shown in fig. below.

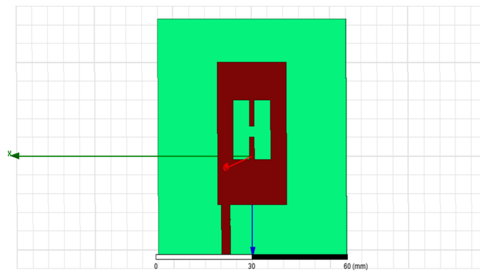

Fig3: Rectangular microstrip patch antenna with single H shape slot

MODIFIED DESIGN FOR TRI-BAND ANTENNA

Furthermore, to increase the number of frequency band the proposed microstrip patch antenna with H shaped slot is odified by inserting a double I-shape slot on the radiating patch.. The Hfss model for the I-shape slot is as shown in fig. below.

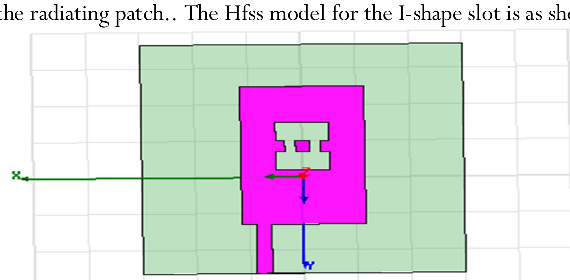

Fig4: Rectangular microstrip patch antenna with double I- shape slot

By introducing the Double I-shape slot in the antenna structure the number of frequency bands is increased and the frequency response of S11 parameter is improved which is described in the next section.

SIMULATION AND RESULTS

The software used to model and simulate the proposed and modified microstrip patch antenna is Hfss i.e.high frequency simulation software. It has been widely used in the design of tunable filters, patch antennas, wire antennas, and other RF/wireless antennas. It can be used to calculate and plot the S11 parameters, VSWR plot,directivity , smith chart, current distributions as well as the radiation pattern. The simulation is done for three cases. The first one is for simple rectangular microstrip patch antenna for 2.4 Ghz frequency band. Antenna structure with H-shaped slot as described in section II and third one is for modified antenna structure with double I-shaped slot described in section III.

Case-I Antenna structure with rectangular shape patch

The rectangular shape microstrip patch antenna is designed for 2.4 GHz. The return loss plot , VSWR plot , radiation pattern and current distribution for the antenna is as shown in figures below.

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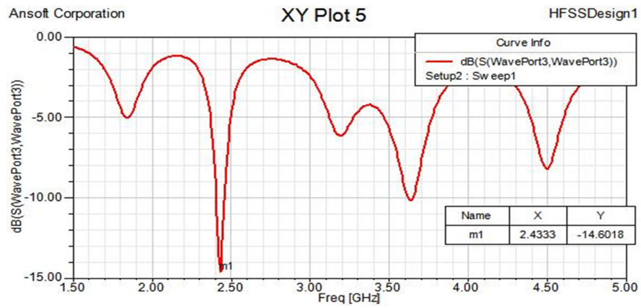

Fig5: s11 plot of rectangular microstrip patch antenna

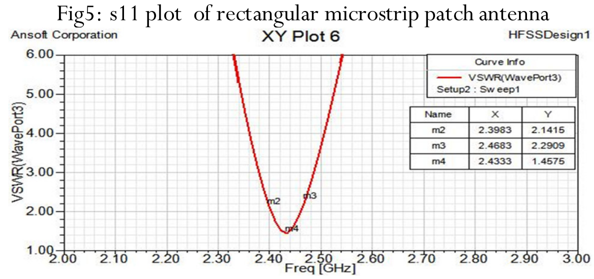

Fig6: VSWR plot of rectangular microstrip patch antenna

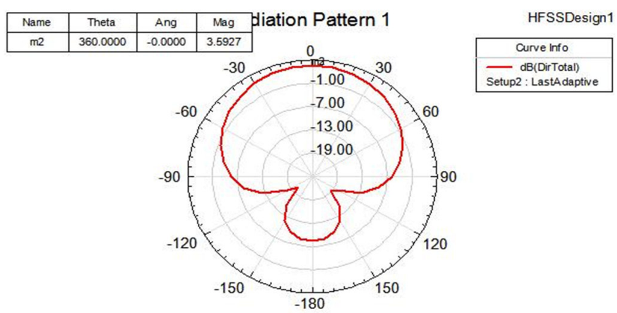

Fig7: Radiation pattern of rectangular microstrip patch antenna

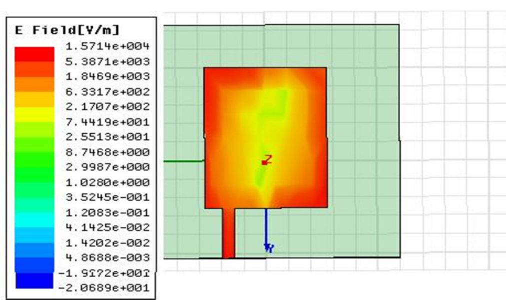

Fig8: current distribution of rectangular microstrip patch antenna

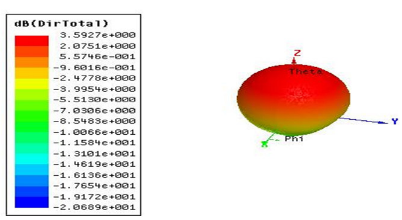

Fig9: directivityt of rectangular microstrip patch antenna

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Case-II Antenna structure with H-shape slot on rectangular shape radiataing patch

The H-shape slot is introduced on the rectangular microstrip patch antenna structure. This antenna structure is covering 2.42-3.59GHz. This antenna structure has two distinct frequency bands, centered at 2.42 GHz, 3.59 GHz as shown in the Fig. 3. As shown in Fig.3 the return loss is less than -10 dB which showing that this antenna is workable on these two frequency bands. The radiation patterns of dual-band antenna of directivity at theta is 90 degree for three resonance frequencies are shown in Fig. 5, 6, 7. The directivity of antenna is described by the shape of the radiation pattern, so from the Fig.5, 6, and 7, it is clear that the radiation pattern is Omni-directional but it becomes directional when operating frequency band is increased.

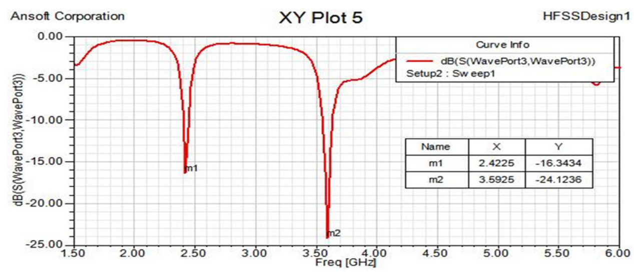

Fig10: s11 plot of microstrip patch antenna with single H shape slot

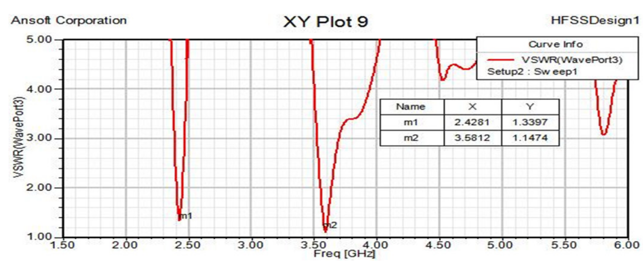

Fig11: VSWR plot of microstrip patch antenna with single H shape slot

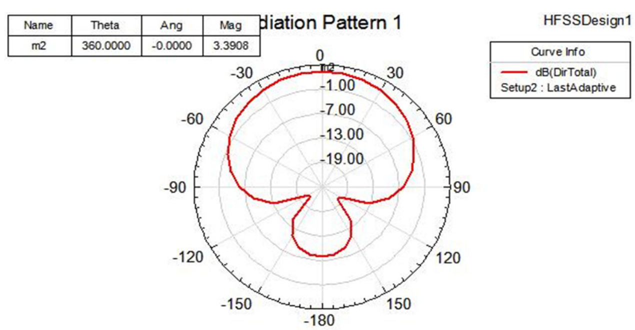

Fig12: Radiation pattern of microstrip patch antenna with H shape slot

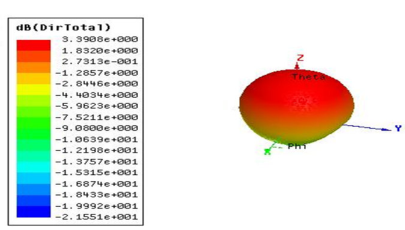

Fig13: Directivity of microstrip patch antenna with single H shape slot

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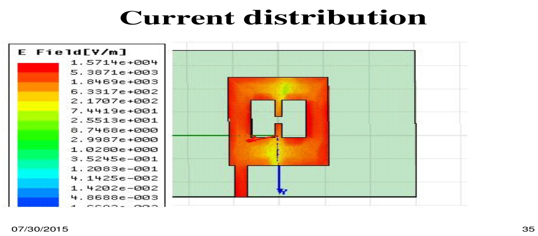

Fig14: current distribution of microstrip patch antenna with H shape slot

Case-III Antenna structure with Double I-shape slot on rectangular shape radiataing patch

As shown in Fig. 3, the return loss of basic antenna structure is tuned for two frequency bands. For improvement of the return loss and increment by one more frequency band, a double I-shaped slot is inserted in the proposed structure. Therefore, this structure works as a tri-band microstrip antenna. As shown in the Fig. 8, proposed structure has three distinct frequency bands centered at 2.44 GHz, 3.54 GHz, 5.37 GHz and 11.35GHz. and operating range from 2.44-5.37 GHz. So the proposed structure has more smooth and extra operating frequency band than the basic antenna structure.

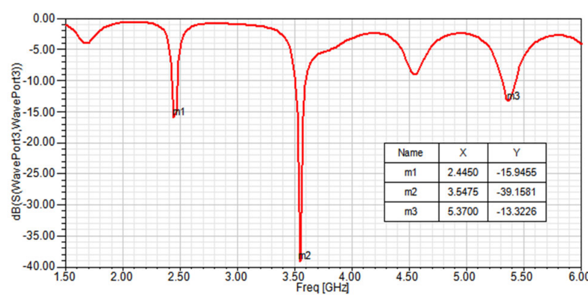

Fig15: s11 plot of microstrip patch antenna with double I- shape slot

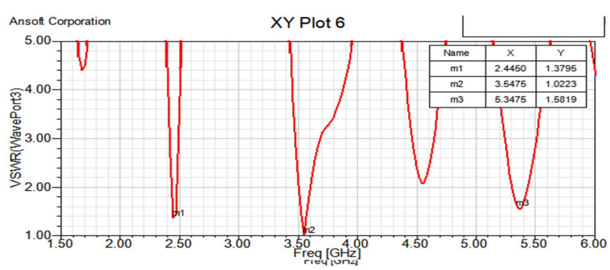

Fig 16: VSWR plot of microstrip patch antenna with double I- shape slot

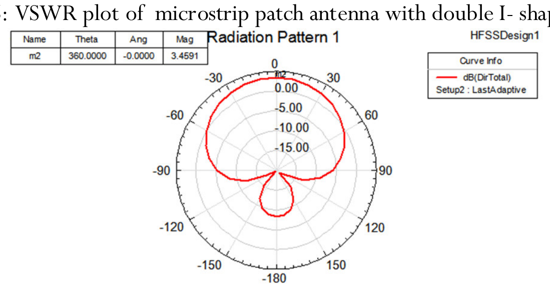

Fig 17: Radiation pattern of patch antenna with double I- shape slot

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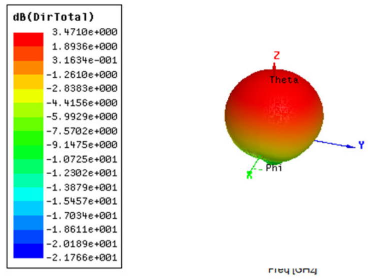

Fig18: Directivity of microstrip patch antenna with double I- shape slot

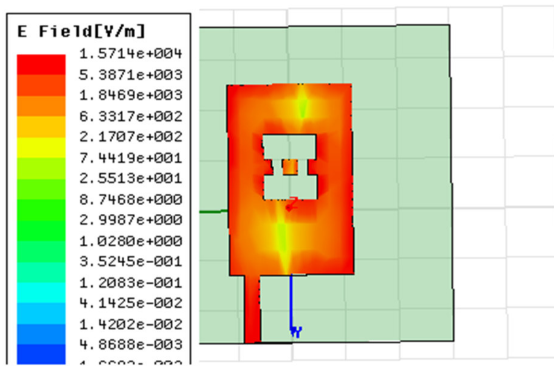

Fig 19: current distribution of patch antenna with double I- shape slot

Comparisons table of simple patch, patch H-shape slot and patch with double I-shaped slot

S.N.	**Shape of MSA**	**Freq (GHZ)**	**Return Loss (dB)**	**VSWR**	**Band width (MH)**	**Directivity (dB)**
1.	Simple patch antenna	2.43	-14.60	1.45	68	**3.59**
2.	Patch with H shaped slot antenna	2.42	-16.34	1.33	53	**3.39**
		3.59	-21.12	1.14	90	
3.	Patch with double I shaped slot antenna	2.44	-15.94	1.37	54.76	**3.47**
		3.54	-39.15	1.02	51.10	
		5.37	-13.32	1.58	47.58	

CONCLUSION

In this paper, a new approach to multiband antenna structure is shown for increasing the number of operating frequency bands and improvement in return loss. The comparison between patch antenna with H-shape slot and with double I-shape slot is shown. From comparison table, the conclusion the future aspect of this work is to increase the number of operating frequency bands by made change using different shaped structures in place of H-slots and I-slots. This structure can be further modified by increasing the switch-ability

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of radiating patch by connecting PIN diode or RF-MEMS switch in switchable slot. The modified antenna are very valuable for many modern wireless applications and radar system applications, such as object detection, secure communication, multi frequency communication and multi frequency communication These proposed antennas can be used for multiband wireless communication applications.

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