Dual-band Antenna with Slots for Wireless Portable Systems

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Abstract - A printed patch antenna that facilitates dual-band frequency operation for wireless communication applications has been presented in this paper. The presented antenna facilitates operation at the frequencies of 2.4GHz and 3.5GHz which are useful in wireless communication applications such as Bluetooth 2.0 and Wi-MAX. A low loss Fire Retardant-4 has been used to design the antenna having relative permittivity ε_r = 4.4 and dielectric loss tangent of 0.02. The presented multi-band frequency antenna has dimensions of 70 × 60 × 2.87mm^3. Coaxial feed has been used as feed to the proposed rectangular patch antenna. A considerable gain of 7.69dB and 5.78dB for the operating frequencies of 2.4GHz and 3.5GHz accordingly is observed. The geometrical shape of antenna consists of two symmetrical square slots placed equidistant from a cross-slot in the centre of radiating patch which provide the dual-band operation.

***Key words*- Linear polarization, single layer, multi band, HFSS, Return Loss.**

1. INTRODUCTION

Patch antennas because of their low weight and profile, conformability, and ease of integration with monolithic microwave integrated circuits (MMICs) are commonly deployed for wireless applications. With the growing needs of the users to have multiple applications in a single device need of having multiband antenna has drastically increased. Hence, antenna designers have to design a compact antenna that facilitates multi-band operation which can serve the user requirements. Antenna should be compact and should easily integrate in any PCB or MMIC circuit so that the overall system size will not be affected by the antenna. To address all these issues microstrip antenna is a promising candidate which can meet all the requirements **[1, 2].**

Microstrip patch antenna suffer major limitations of low bandwidth and gain. To minimize these limitations, number of techniques to enhance gain and bandwidth such as etching slots in patch or ground, using diodes, shorting pins, shorting walls, vias or choosing proper feeding technique **[3]** have been proposed. Multiband patch antenna design can be subdivided into following categories: 1) multi-resonator antennas and 2) reactive loading antennas.

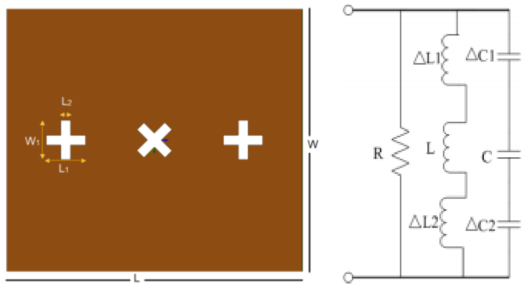
Within the case of the former category of multi-band antenna, multiband operation is obtained by integrating various radiating elements that facilitate radiation at resonance frequency due to strong supporting currents. Multilayer stacked-patch antennas manufactured by employing circular **[4],** annular **[5],** rectangular **[6],** and triangular **[7]** patches are listed in this group. A multi-resonator multi-band antenna fabricated on a single dielectric layer by using aperture-coupled parallel rectangular dipoles is reported in **[8].** Unfortunately, unavailability of simple and accurate design formulas in existing literature limits the use of the design of the frequency ratio (FR) parameter for all the multi-resonators structures.

In case of the second category of multi-band antenna, dual-band frequency function is obtained by using one radiating element by coupling coaxial **[9]** or microstrip **[10]** stubs within radiating edge of the patch. The above-mentioned multi-band antenna design techniques provide maximum FR of 1.2. Higher values of FR (>4) have been reported in **[11]**, which have been achieved by placing dual lumped capacitors across the radiating patch as well as ground plane**.** Within [**12**]-[**13**], the dual-band performance is achieved by a technique of using symmetrical shorting vias. Other techniques to achieve reactive loading consists of carving slots over the radiating patch. The slots in the radiating patch allows strong modifications within resonant modes of the patch, predominantly at the time slots alters current flow of a unexcited mode. Particularly, as demonstrated in **[14]**, the concurrent usage of slots in the radiating patch as well as short-circuit vias, enables us to acheive certain FR ranging about **1.3** to **3** as a function of the number of vias. The U, E, S or H slots in the radiating patch that facilitate multi-band operation have been reported [**15**], **[16],** and [**17**] respectively. The dual band antenna presented in this research comprised of a simple rectangular patch antenna along with square slots engraved on the patch and fed with a coax feed.

2. CONFIGURATION OF PROPOSED ANTENNA

The presented dual-band antenna comprised of a simple rectangular patch along with dual symmetrical square slots engraved within the radiating patch placed equidistant from a cross slot engraved in center of the radiating patch. The antenna is feed with coaxial feeding to have impedance of 50Ω. A low loss FR-4 substrate is used for modelling the antenna. The presented quad-band antenna is has dimensions of 70 × 60 × 2.87 mm^3. The modelling and design of the presented antenna is done by using Ansys HFSS EM simulation software **[18**].

Fig 1. Simulated Antenna model (Top view)



(a) (b)

Fig 2. (a) Schematic and (b) Equivalent circuit pertaining to radiating patch

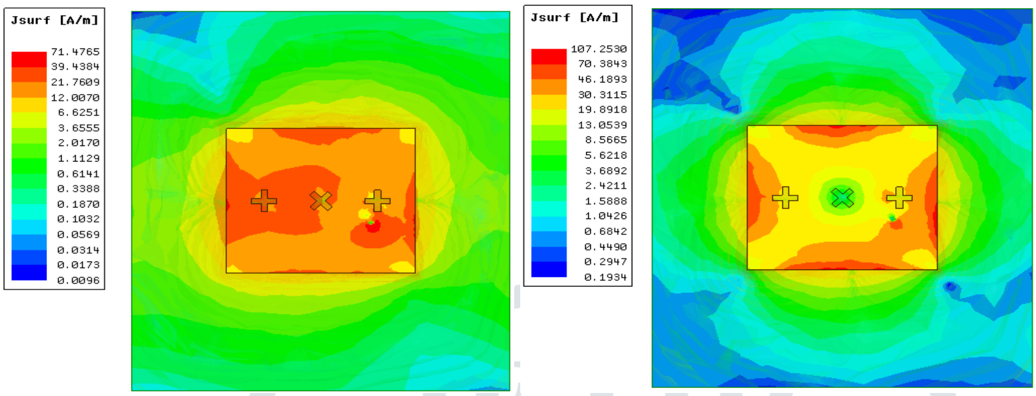
The rectangular radiating patch possesses dimension about 30 × 26.7 mm^2. The square and cross slots that provide multi-band are placed 3mm apart from each other and have dimension of 12 × 12 × 2.3mm^3. Fig. 1 depicts the top view of the simulated antenna while Fig. 2 depicts the schematic and corresponding equivalent circuit of the proposed radiating element. The presented antenna resonates at the frequencies of 2.45GHz and 3.5GHz. The final optimized dimensions were tabulated in Table 1 below.

TABLE I Optimum dimensions of the presented antenna

Attribute	Magnitude (mm)
L	30.0

W	26.7
L1	12.0
L2	2.30
W1	12.0

Fig. 3 below depicts the simulated surface current variation in the presented antenna for different operating frequencies. From Fig. 3, we can observe that the current flow at different areas of the radiating patch is responsible that for the resonance at different operating frequencies.



a. 2.45 GHz b. 3.5GHz

Fig 3. Simulated surface current distributions

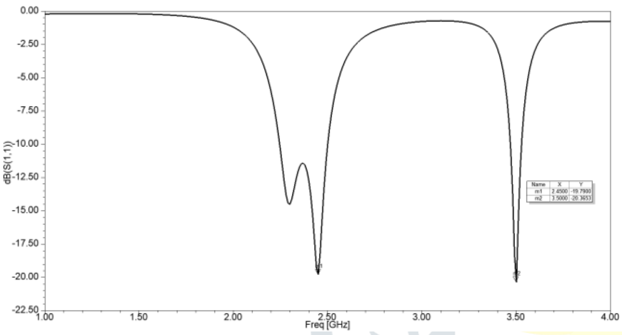


Fig 4. Return loss

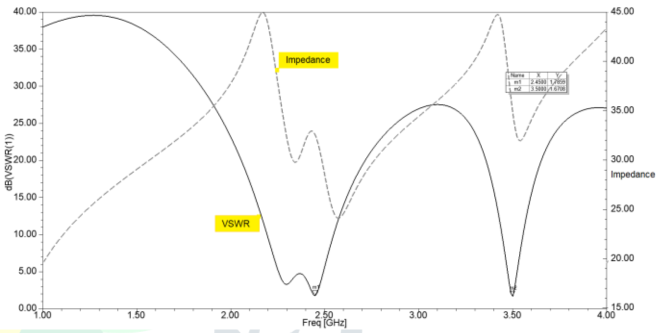
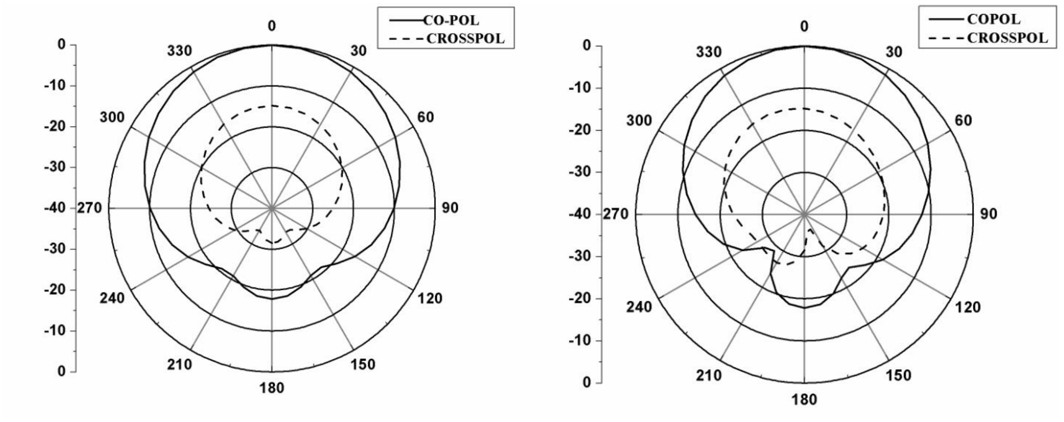


Fig 5. VSWR and Impedance variation

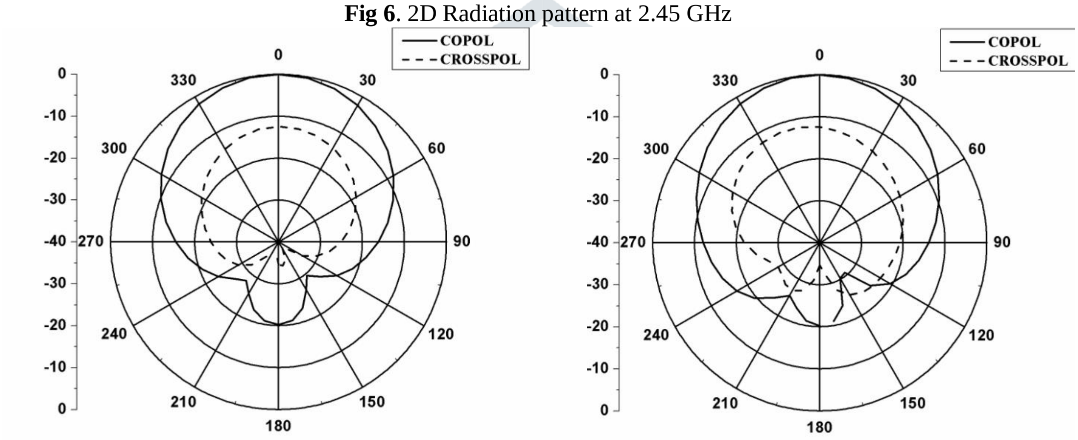
3. RESULTS

The functioning of the symmetrical slotted antenna resonating at the dual frequencies is analysed using Ansys HFSS software. Performance of antenna is analyzed and investigated in terms of various antenna characteristics like gain, current distribution, return loss(dB), VSWR and 2D radiation pattern. All the above-mentioned characteristics were analysed for all the resonating frequencies. Figure 4 below depicts the return loss(dB) plot of the presented antenna, a return loss about -19.79 dB and -20.35 dB are observed during the operating frequencies of 2.45 GHz as well as 3.5 GHz accordingly. From the return loss values achieved we can say that the antenna is having a better impedance matching along all the resonating frequencies. Fig. 5 below depicts the VSWR and impedance variation of the symmetrical slotted antenna a VSWR of 1.78 and 1. 67 is observed at the operating frequencies of 2.45 GHz as well as 3.5 GHz accordingly. The impedance reaches 45Ω about the operating frequencies ensuring proper impedance matching. Fig. 6 and 7 below depicts the two-dimensional radiation characteristics in terms of elevation plane and azimuthal plane for the symmetrical slotted antenna resonating at the three operating frequencies of 2.45 GHz and 3.5 GHz respectively.



(a) E-plane (b) H-plane

Fig 6. 2D Radiation pattern at 2.45 GHz



(a) E-plane (b) H-plane

Fig 7. 2D Radiation pattern at 3.5 GHz

Fig. 8 as well as Fig.9 depicts the presented antenna gain variation for the operating frequencies of 2.45 GHz as well as 3.5 GHz. Observed a gain of 7.69dB and 5.78dB for the operating frequencies of 2.45 GHz as well as 3.5 GHz respectively. Fig. 10 shows the photographic view of the manufactured prototype. Fig. 11 shows the similarity attributed to simulated and measured return loss of the presented antenna. The measured results validate the operation of the presented antenna. The presented antenna provides measured -10 dB bandwidths of 0.11 GHz (2.4 – 2.51 GHz) and 0.34 GHz (3.29 – 3.63 GHz) respectively.

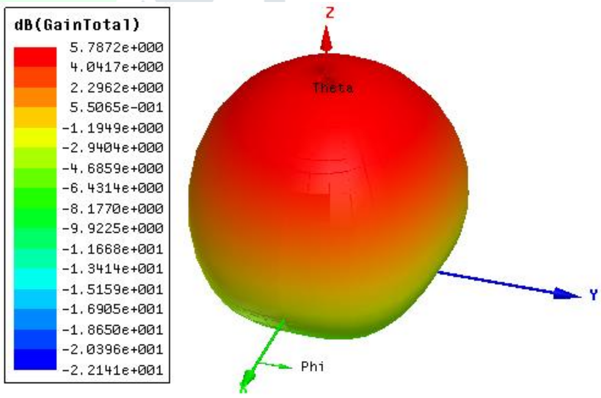


Fig 9. Gain variation at 3.5 GHz

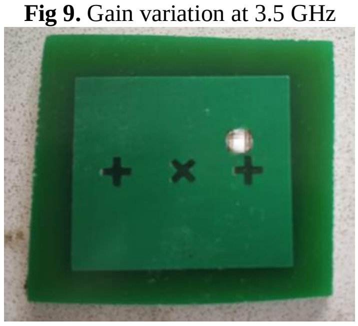


Fig 10. Photographic view of fabricated antenna

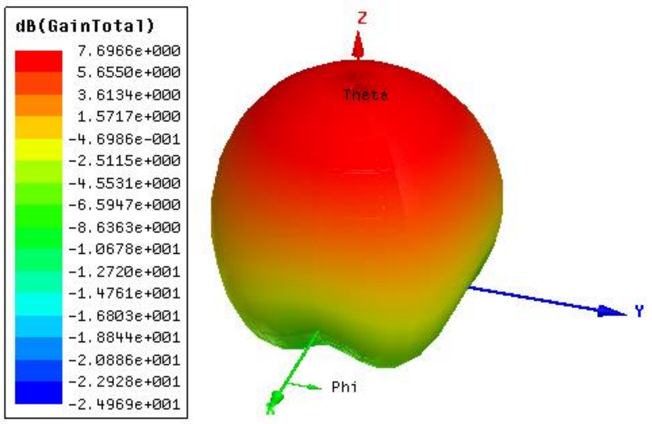


Fig 8. Gain variation at 2.45 GHz

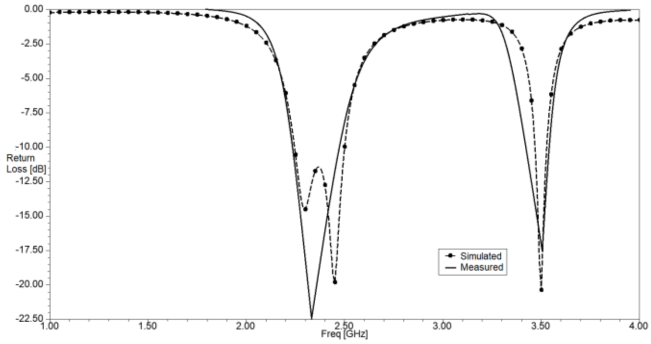


Fig 11. Measured Vs simulated return loss

4. CONCLUSION

In this research article, a simple dual frequency printed rectangular patch antenna with coax feed is presented and the performance is analysed. The antenna resonates at the frequencies of 2.54GHz as well as 3.5 GHz respectively. The radiating element is having two symmetrical square slots and one cross-shaped slot which are responsible for the multiple resonance. From the above-mentioned antenna performance characteristics, it is evident that the antenna designed is best suited for the wireless applications.

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