Dual Band Microstrip Patch Antenna with I & T Shaped Slots on the Ground Plane

Ajay Kumar Dwivedi
M.Tech Scholar
Department of Electronics & Communication
SSET, SHIATS, Allahabad

Rajeev Paulus
Professor
Department of Electronics & Communication
SSET, SHIATS, Allahabad

A.K Jaiswal
Professor & Head
Department of Electronics & Communication
SSET, SHIATS, Allahabad

Aditi Agrawal
Assistant Professor
Department of Electronics & Communication
SSET, SHIATS, Allahabad

ABSTRACT
A new dual band microstrip patch antenna with I & T slots on the ground plane has been designed. Observation has been made for the two resonant frequencies in 2.23-2.37 GHz and 4.60-4.76 GHz bands with improved impedance bandwidth in comparison to that of reference patch antenna. The proposed antenna can suitably be used in field of WLAN and C-band application. The proposed antenna has manifested the broader radiation pattern with maximum field strength of approximate 15 dB at 2.37 GHz and 5 db at 4.7 GHz with better voltage standing wave ratio which indicates minimum reflection and better impedance matching. The simulation is carried out by high frequency structure simulator.

Keywords
Microstrip patch antenna, slotted ground plane, meandering, HFSS, VSWR, Radiation pattern.

1. INTRODUCTION
A know- how of meandering an antenna's radiating patch is an effective method to obtain the reduced size of microstrip patch antenna [1-3]. Two slots insertion in the non radiating edges of the antenna patch provide an effective way for the meandering technique. Due to the meandering slots, the length for the excited patch surface current paths has increased, it lowers the antenna resonant frequency and we achieve dual band resonating structure. Many compact microstrip antenna designs such as using shorting pin loading, high permittivity substrate etc have been under study, in the proposed design The impedance bandwidth has increased in comparison to conventional microstrip antennas [5-6]. Modifications in microstrip antenna technology have been taking place since 1970. Basic elements of microstrip antenna and its arrays have been utilized for a period of 35 years approximately at a moderate level [8]. For the design of patch and ground on a dielectric substrate material the conductors- copper and gold due to their better conductivity and adhesive property are mostly used [7]. The fringing fields in the gap of patch edge and the ground plane cause electromagnetic wave radiations from the microstrip patch antenna [9]. Narrow bandwidth has been a major demerit of the microstrip patch antenna [10], for the remedial action of narrow bandwidth demerit, has directed many of the researchers have directed towards other approach such as meandering and some useful U- slots [11]. For dual band and multi band operations a critical analysis has been performed on the U-slot patch antennas [12].

In this paper, we suggest a new compact microstrip antenna along with meandering slots in the ground plane as shown in Figure 1. The proposed patch is resonant at two frequencies which are suitable for WLAN and C band applications [4]. Embedding the I and T slots in the ground plane of the patch antenna has increased the quality factor of the suggested design. The impedance band width and the antenna field pattern both have also been achieved larger than those of the corresponding conventional microstrip patch antenna.

2. ANTENNA DESIGN
Figure 1 shows the two dimensional view in X-Y plane of the suggested microstrip patch antenna with I & T slots in ground plane. The ground plane and the rectangular radiating patch are made of copper and the dimensions of the substrate material FR-4 and that of the ground have taken 50 mm × 50 mm in X-Y plane. The two slots of shapes I and T have been etched out from the ground plane and the coaxial probe feed point at a position d_p = 5 *mm* from the patch centre along with the Z axis is set between them.

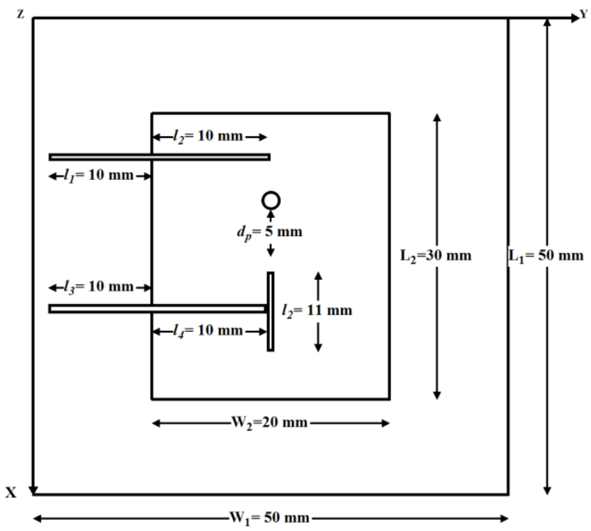


Fig 1: Structure of proposed antenna

The rectangular radiating patch having dimensions of L = 30 *mm* and W = 20 *mm* is printed on a microwave substrate of thickness h = 1.6 *mm* and relative permittivity $\varepsilon_r = 4.4$ and the etched slots with a narrow width 1 mm. In this study we have length of l_1 = 10 *mm* and l_2 = 10 *mm*, where l_1 and l_2 being the I-slot length outside and inside the projection image of the radiating patch in the ground plane respectively. For the convenience Table I display dimensions of the antenna.

3. RESULT AND DISCUSSION

The proposed antenna is constructed and analyzed using high frequency structure simulator (HFSS) electromagnetic solver based on finite element method. The field patterns of patch antenna are 15.66 dB, 17.55 dB at 2.32 GHz and 4.7 GHz respectively, return loss of -17 dB, -20.44 dB in the lower band of 2.23-2.37 GHz and the upper band 4.60-4.76 GHz respectively.

The impedance bandwidths at -10 dB of the proposed patch antenna have been observed to be 6.03% and 3.03% in the lower band and the upper band respectively which are the improved results in comparison to the reference patch without slots.

Table 1. Dimensions of proposed Antenna

Substrate length (L_1)	50 mm
Substrate width (W_1)	50 mm
Substrate thickness (h)	1.6 mm
Patch length (L_2)	30 mm
Patch width (W_2)	20 mm
I- slot (l_1)	10 mm
I- slot (l_2)	10 mm
T- slot (l_3)	10 mm
T- slot (l_4)	10 mm
T- slot (l_5)	11 mm
Slot gap width	1 mm

The return losses for the proposed antenna and the reference antenna have been shown in Figure 2.

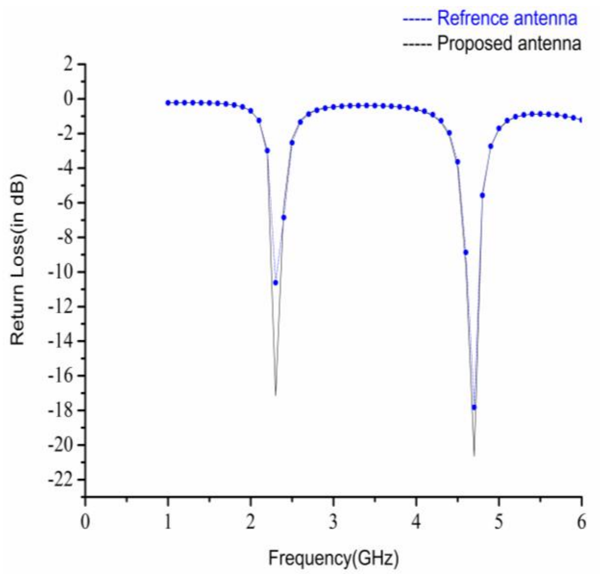


Fig 2: Return loss for reference Antenna and proposed Antenna

The value of VSWR is less than 2 for operating frequencies range. The simulated results for the proposed microstrip patch antenna in terms of radiation pattern, Field pattern (at both central frequency) and voltage standing wave ratio (VSWR< 2) are shown in Figure 4 and Figure 5 respectively. In figure 3 the radiation field pattern for reference patch antenna is shown, at lower frequency proposed patch antenna has no sharp back lobe. The back lobe just beneath the patch radiation pattern in Figure 3 has been eliminated and improved result is shown in Figure 4.

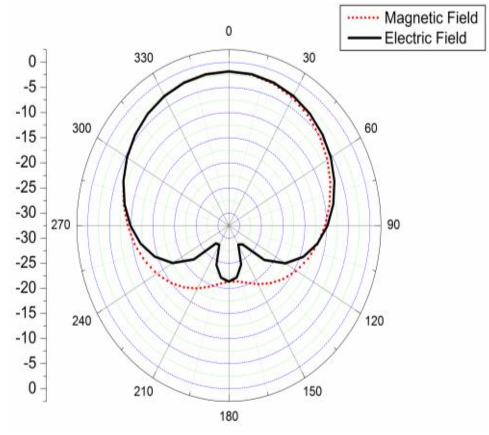
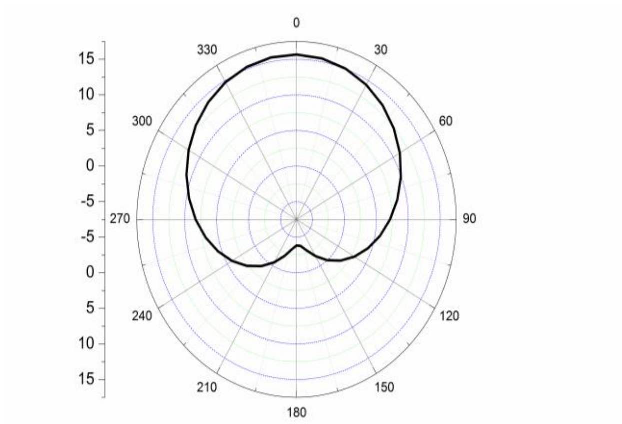
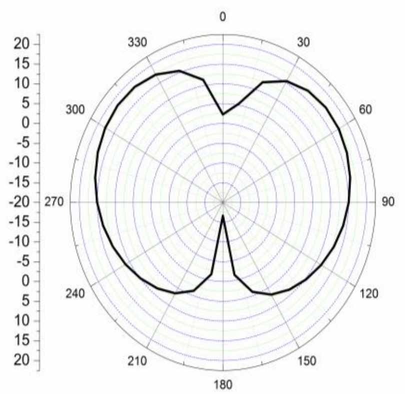


Fig 3: Electric field and magnetic field pattern of reference antenna



(a)



(b)

Fig 4: Field pattern of proposed antenna at (a) 2.32 GHz (b) 4.7 GHz

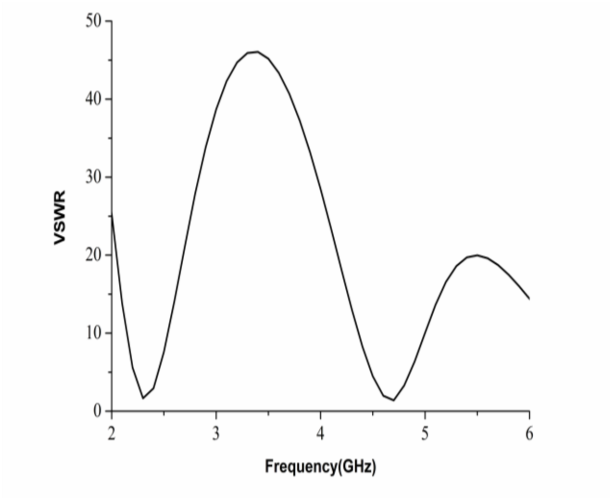


Fig 5: VSWR for proposed patch antenna

The electric field distribution is shown in Figure 6. The maximum electric field distribution attained over the patch at 2.3 GHz is 4.65×10^3 V/m but its expansion tends towards a corner of the plane of the patch. The radiation in broad area of the patch takes place near the probe with average field strength of 2.33×10^3 V/m. The field distributed is of less magnitude, it means the near field distribution which is of no significance is achieved to be less but far field distribution is up to the standard.

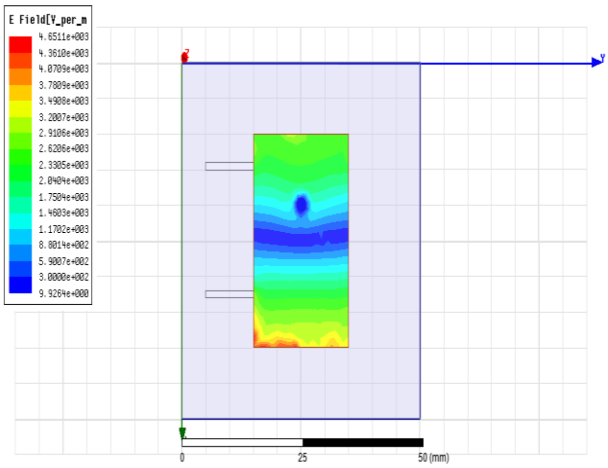


Fig 6: Electric field distribution at 2.37 GHz

The probe surrounds with magnetic field of 8.3×10^2 A/m at 2.37 GHz. The non radiating edge accompanies with 4.38 A/m magnetic field. Most of the middle part of the patch exhibits a radiation from 25 A/m to 47 A/m over the upper hemisphere of the patch plane. 68.8 A/m strength has been observed at the tip of the probe. The magnetic field distribution at 2.37 GHz has been shown in Figure 7.

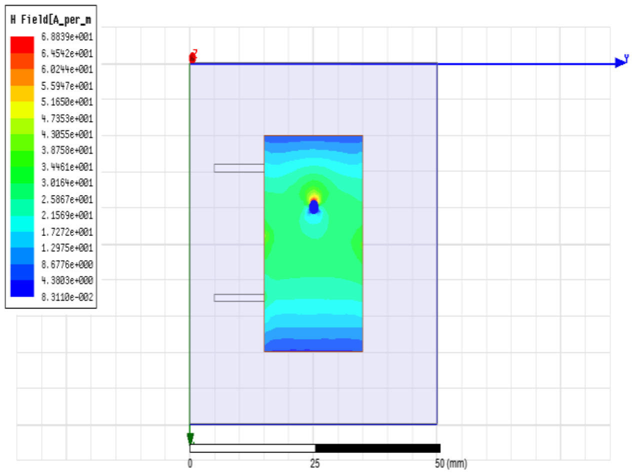


Fig 7: Magnetic field distribution at 2.37 GHz

The Electric field distribution at 4.7 GHz, near the probe feed position the radiated field propagates in two directions towards the non radiating edge corners with 6.6×10^2 V/m and also spreads along a strip parallel to the non radiating edge with approximate same strength over the I-slot in the ground as shown in Figure 8. The mid area of the slot in the ground has denser distribution with 2.9×10^3 V/m over the patch. The maximum field strength occurs over the radiating edge with 5.2×10^3 V/m.

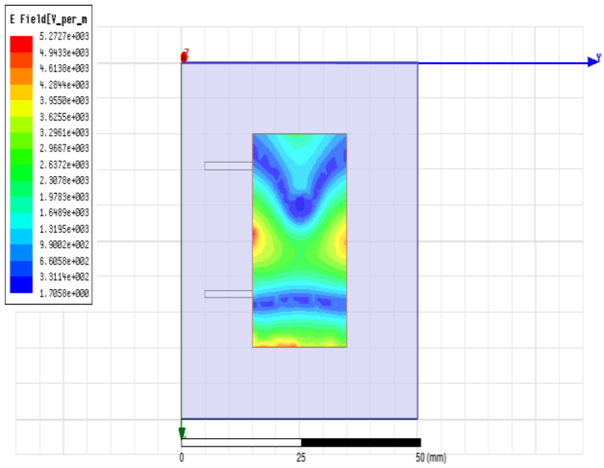


Fig 8: Electric field distribution at 4.7 GHz

The magnetic field distribution at 4.7 GHz shown in Figure 9, has the least field strength around the probe and the mid of the patch is also filled with a strip wise magnetic field of 9.85 A/m and it increases up to 23.8 A/m. The magnetic field strength approximates up to 47.13 A/m over the large part of the patch. The magnetic field parallel to the non radiating edge is 19.2 A/m.

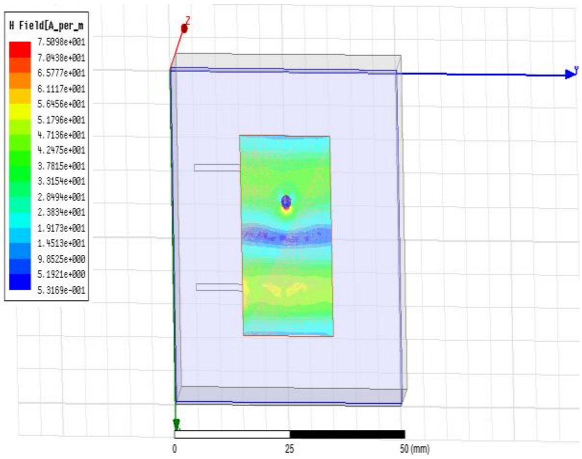


Fig 9: Magnetic field distribution at 4.7 GHz

4. CONCLUSION

A novel design of compact microstrip patch antenna with a meandered ground plane has been proposed and analyzed using HFSS. By providing the meandering slots of I and T shape on the conductive ground plane, it is observed that the dual band compact resonating structure with minimum value of return loss has been obtained for dual operating frequency ranges. The structure can be suitably used for WLAN and C-Band applications. In future the structure is expected to be modified for rectenna with the help of Advanced Design System software.

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