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# RADIAL STUB LOADED ANTENNA WITH TAPERED DEFECTED GROUND STRUCTURE

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## ABSTRACT

A compact pentagonal shaped slot antenna for multiband applications is proposed. The antenna comprises of a T-shaped patch on one side of the substrate. The top surface of the patch consists of a serrated edge for bandwidth enhancement. The antenna is fed by a 50-Ω microstrip line. A Defected ground structure is employed by placing a pentagonal slot in the ground plane of the antenna. The antenna possesses a compact physical structure with dimensions of 30 x 30 x 1.6 mm and is printed on FR4 epoxy substrate with dielectric constant 4.4. Simulations are carried out using Ansys HFSS. The proposed antenna exhibits a -10 dB magnitude for frequency bands 2.5-3.02 GHz, 4.59-7.053 GHz and 13.06-13.48 GHz covering various multiband applications. The antenna is fabricated successfully and is further characterized by measuring VSWR, radiation pattern and gain. The measured results are in good agreement with that of the simulated ones.

**Keywords:** pentagonal slot, T-shaped patch, serrated edge, multiband, defected ground structure, microstrip line feed.

## 1. INTRODUCTION

Printed wide slot antennas have gained significant attention because of their wide impedance bandwidth exhibiting property. In addition, they are completely planar and are easily integrate with other devices [1-3]. A growing interest for microstrip line fed printed wide slot antennas is been observed in the recent years. The use of slots will provide an impedance bandwidth improvement as compared to a simple patch antenna. The use of multiple slots will provide multiple resonant frequencies [4-6]. Combining these multiple resonant frequencies will result in a wideband nature or Ultra-wideband nature [7-8].

The DGS can be regarded as a simplified form of Electromagnetic Band Gap (EBG) structure. It has become a promising alternative due to its compact size and easy implementation. Initially, dumbbell shaped DGS was used to realise a filter and later shapes were experimented to realize different microwave structures [9-10]. The DGS may comprise of a single unit cell, a number of periodic or aperiodic configurations [11-12]. In planar microstrip circuits, DGS is located beneath a microstrip line and it perturbs the electromagnetic fields around the defect. Capacitive effects are accounted for trapped electric fields and inductive effects are accounted for surface currents around a defect [13-15].

In this work, we propose a pentagonal wide slot antenna fed by a microstrip line with a T-shaped tuning stub comprising of a serrated edge on one side. By employing a tuning stub wideband operation is achieved. The simulation has been carried out in HFSS13. The proposed antenna exhibits a -10 dB magnitude for frequency bands covering 2.5-3.02 GHz, 4.59-7.053 GHz and 13.06-13.48 GHz covering various multiband applications. A satisfactory matching is observed in the VSWR of the simulated and measured antenna results. A peak gain of about 4.5 dBi is observed for the final proposed antenna. Detailed study of the proposed antenna along with the simulation results is further discussed in detail.

## 2. ANTENNA DESIGN AND GEOMETRY

The basic model of the proposed antenna on a defected ground structure is as shown in Figure-1 (a). The proposed antenna occupied a compact size of about 30 x 30 x 1.6 $mm^2$. The radiating patch element of the antenna is initially perfect T-shaped. A pentagonal slot is employed in the ground plane. The basic design has undergone some modifications in the ground plane where a defected ground structure (DGS) is employed. The DGS is an etched periodic configuration defect in the ground plane which disturbs the current distribution in the ground plane. This etched defect in the ground plane leads to enhancing effective inductance and capacitance. With the application of DGS radiation characteristics of the antenna are improved. The final proposed model antenna employs a serrated edge on one side of the T-shaped radiating patch element as shown in Figure-2. The edge serrations on the T-shaped radiating patch provide an improvement in the bandwidth.

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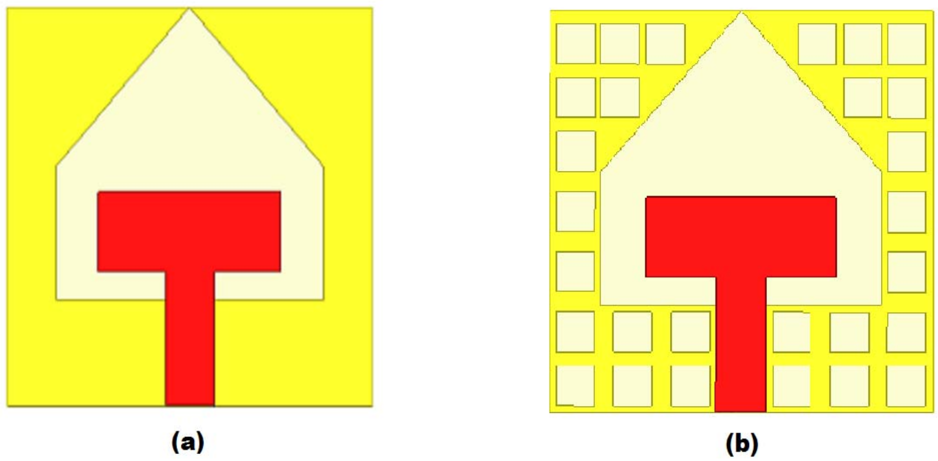


**Figure-1.** Slot antenna (a) Basic model (b) Design with DGS in the ground plane.

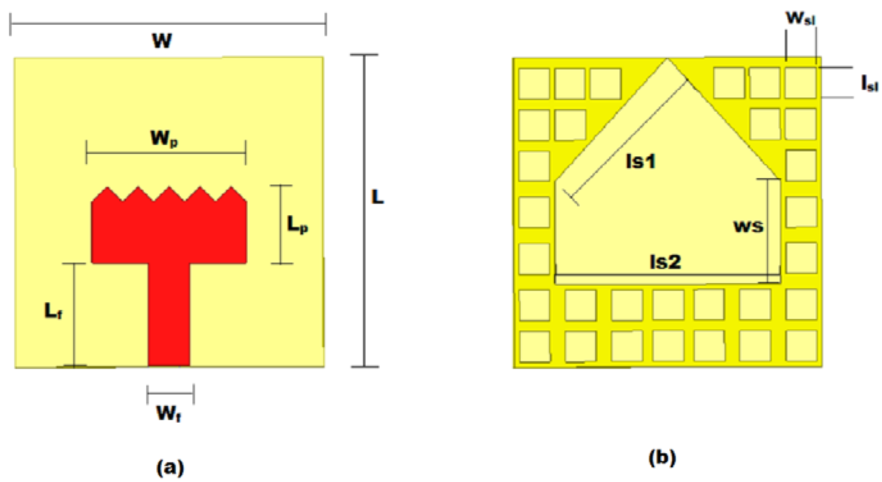


**Figure-2.** Final proposed antenna (a) Front view (b) Back view.

**Table-1.** Dimensions of the proposed antenna.

| Parameter | L | W | Wp | Lp | Lf | Wf |
|---|---|---|---|---|---|---|
| Dimension mm | 30 | 30 | 15 | 6 | 10 | 4 |
| Parameter | Ls1 | Ls2 | Ws | Wsl | Lsl | |
| Dimension mm | 16.2 | 22 | 10 | 3 | 3 | |

The final proposed antenna is printed on Fr-4 Epoxy substrate and the dimensions of the antenna are presented in Table.1 as shown above. All the dimensions of the proposed model as indicated in the table are in mm. A periodic DGS with square shaped geometry is employed in the ground plane of the proposed antenna. In addition, a pentagonal slot is also present in the ground plane of the antenna which improves the radiation performance of the required antenna.

## 3. RESULTS AND DISCUSSIONS

The basic model of the antenna is compared with the proposed model and the simulated compared results are plotted in Figure-3. The basic antenna has a bandwidth ($S_{11}$ < -10 dB) from 2.6 - 3.1 GHz and from 5.32 - 7.32 GHz providing multiband operational functionality. The basic antenna does not cover the required frequency bands and it is out of our desired applications. The modified model with defected ground structure embedded in the ground plane of the antenna exhibits -10 dB bandwidth in

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the frequency ranging from 2.5 - 2.7 GHz, thus covering the 2.5 GHz (2.5- 2.69 GHz) for Wi-MAX applications. The antenna also partially covers the WLAN band which is not suitable for perfect functionality. The final Proposed antenna model has a bandwidth ($S_{11}$ < -10 dB) from 2.5-3.02 GHz, 4.59-7.053 GHz and 13.06-13.48 GHz covering various multiband applications including Wi-MAX and WLAN. Thus, the proposed antenna is suitable for multiband applications.

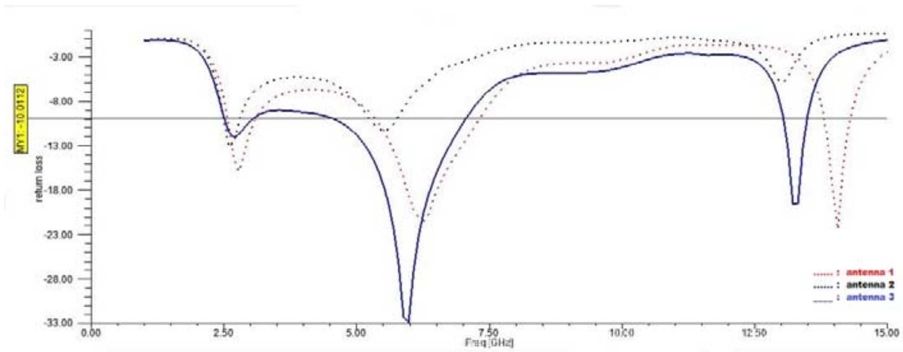


**Figure-3.** Reflection coefficient of the basic antenna and the proposed antenna.

In addition to the reflection coefficient, the VSWR of all the three antenna models are also plotted in Figure-4. The VSWR lies in the range of 1<VSWR<2 in the desired bands of interest.

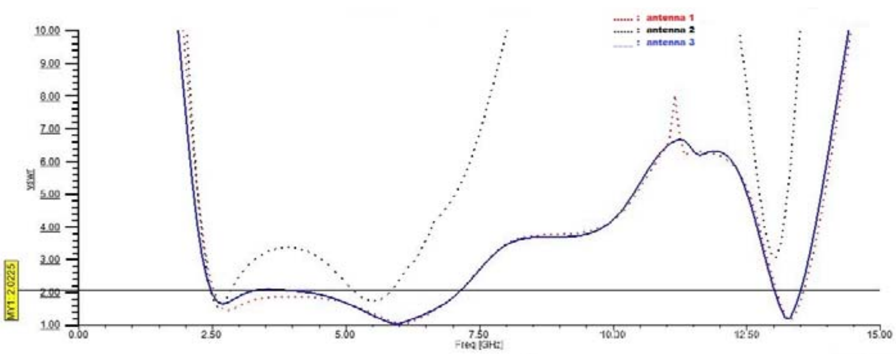


**Figure-4.** Simulated VSWR of the basic antenna and the proposed antenna.

The 2-D radiation patterns of the antenna are simulated as shown in Figure-5. We observe that at a initial frequency of 2.6 GHz, the antenna possess a dumb-bell shape radiation pattern in the E-Plane and a omni directional radiation pattern in the H-Plane.

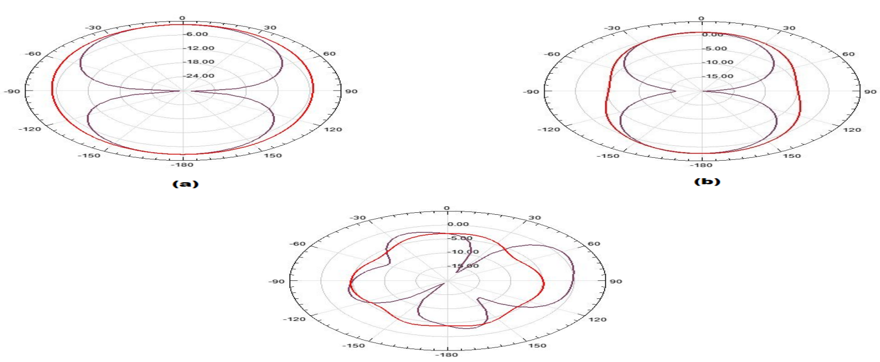


**Figure-5.** 2-D Radiation patterns of the proposed final antenna at (a) 2.6 GHz (b) 5.98 GHz and (c) 13.2 GHz.

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As the frequency increases, at 5.98 GHz the antenna exhibits a radiation pattern which resembles a dumb-bell shape radiation pattern in the E-plane and a omni directional radiation pattern in the H-Plane. The radiation patterns at 13.2 GHz are due to the higher order resonant modes of the proposed antenna. At the initial frequencies the antenna exhibits a radiation pattern similar to that of a planar monopole antenna.

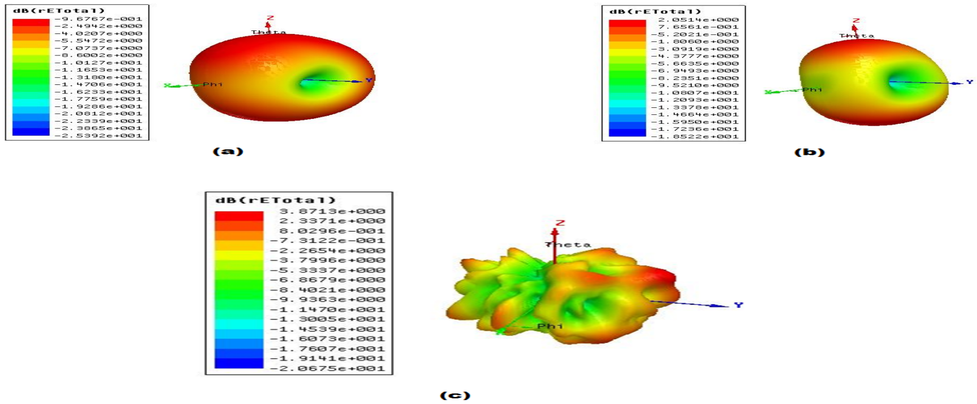


**Figure-6.** 3-D Polar plots of the proposed final antenna at (a) 2.6 GHz (b) 5.98 GHz and (c) 13.2 GHz.

The 3-D polar plots of the final antenna are shown in above Figure-6 for three different frequencies of 2.6 GHz, 5.98 GHz and 13.2 GHz. The antenna exhibits desired characteristics at the initial frequencies. The 3-D polar plot at 13.2 GHz is due to the presence of higher order resonances. The surface current distributions of the proposed antenna at three different frequencies of 2.6 GHz, 5.98 GHz and 13.2 GHz are shown in Figure-7. We observe that at initial frequency of 2.6 GHz most of the current distribution is concentrated on the patch element and along the length of the feed line. Thus, stable radiation patterns are observed at this particular frequency. Similarly at 5.94 GHz frequency, the current distribution is concentrated mostly on the patch element and on the feed line which is also responsible for the stable radiation patterns resembling that of a planar monopole antenna.

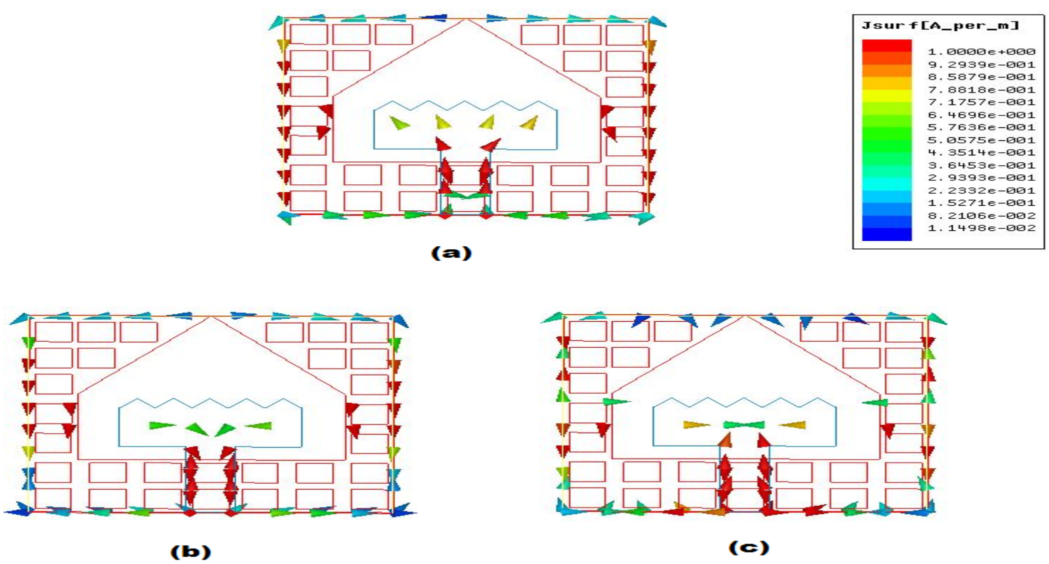


**Figure-7.** Surface current distribution of the proposed antenna at (a) 2.6 GHz (b) 5.98 GHz and (c) 13.2 GHz.

At higher resonant frequency of 13.2 GHz some part of the radiation is present in the ground plane and along the edges of the pentagonal slot which is responsible for distorted radiation pattern at that particular frequency.

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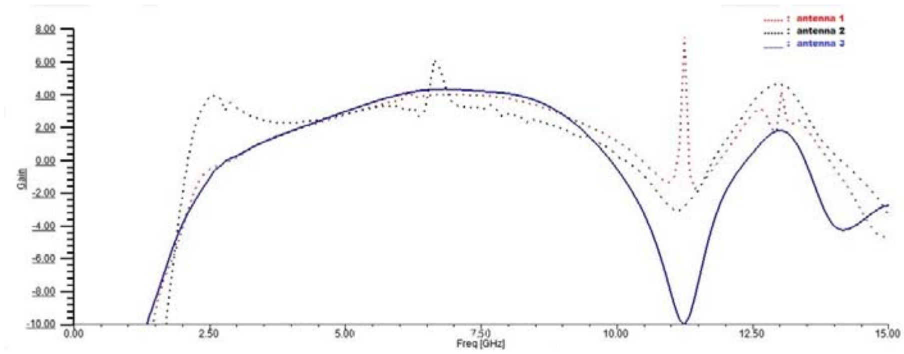


**Figure-8.** Simulated gain vs. Frequency of the basic antenna and the proposed antenna.

The gain vs. frequency plot of the basic antenna along with the proposed antenna is shown in the Figure-8. The final proposed antenna exhibits a stable gain throughout the frequency of operation when compared with the other models. A peak gain of about 4.5 dBi is attained in the desired band of operation for the final proposed model. The gain drops after the initial frequency for the basic model and thereby not satisfying our requirement.

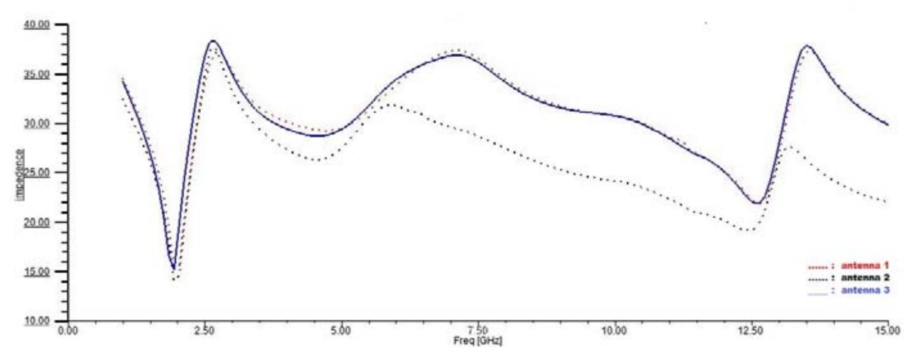


**Figure-9.** Simulated impedance vs. Frequency of the basic antenna and the proposed antenna.

The impedance vs. frequency plot of the antenna models are as shown in Figure-9. The desired impedance is exhibited by the final proposed model when compared with the other models as evident from the above figure.

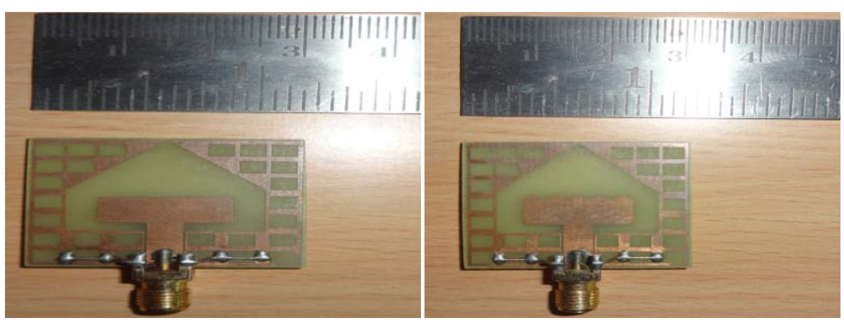

**Figure-10.** Fabricated antennas on FR4 substrate.

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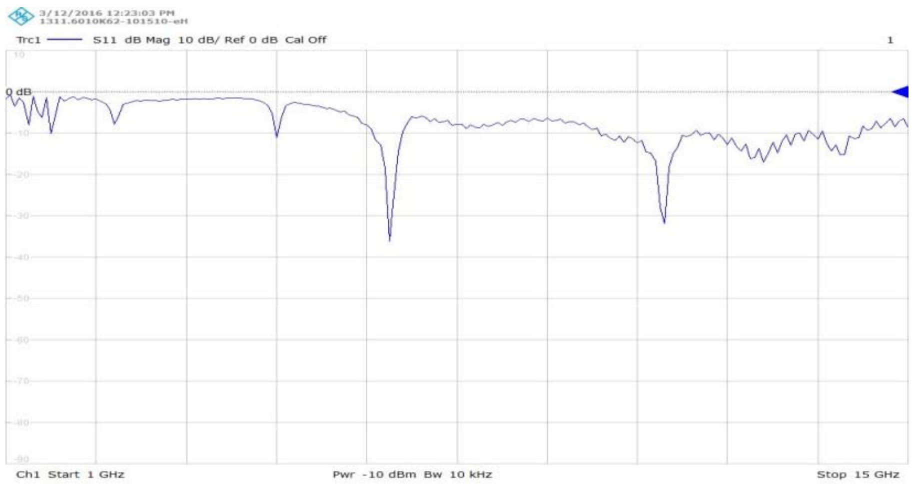


**Figure-11.** Measured S11 of the proposed antenna on ZNB 20 VNA.

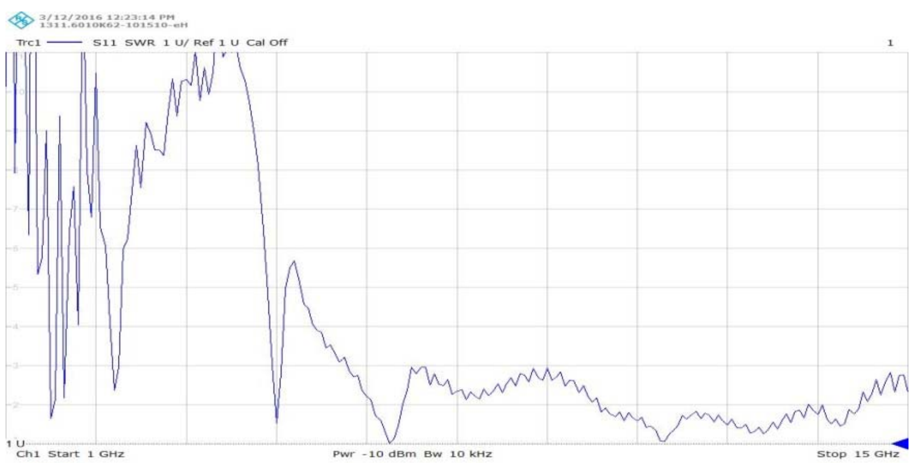


**Figure-12.** Measured VSWR of the proposed antenna on ZNB 20 VNA.

## 4. CONCLUSIONS

A novel pentagonal shaped slot antenna for multiband applications is proposed in this work. The antenna possesses a compact physical structure with dimensions of 30 x 30 x 1.6 mm and is printed on FR4 epoxy substrate with dielectric constant 4.4. Simulation results of return loss, VSWR, radiation pattern and field distributions are analyzed with HFSS tool. The proposed antenna exhibits a -10 dB magnitude for frequency bands 2.5-3.02 GHz, 4.59-7.053 GHz and 13.06-13.48 GHz covering various multiband applications. Antenna models are fabricated and tested for reliability and found equivalent results when compared with simulation results. A peak realized gain of 4 dB and directivity of 3.8 dB is attained from the proposed antenna with serrated stub element.

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