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Rectangular Microstrip Patch Antenna with Partial Ground, Slot, and Step for 5-6GHz IoT Applications

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Abstract: A wideband microstrip antenna is proposed with the partially ground structure for ISM (Industry, Science, Medical) band other wireless applications like worldwide interoperability for microwave access (WiMAX), and wireless local area network (WLAN). The need for compact antennas is continuously growing due to the rapid expansion of applications in today's environment. In this paper, a novel compact broadband patch antenna with an oval patch, rectangular slot, step, and partial ground is presented, which is compatible with ISM band, WLAN, and WiMAX applications. For S_{11}(10dB) the suggested antenna has a bandwidth of 4.78GHz to 6.80GHz. The prototype is constructed on a commercially available FR4 substrate with dimensions of 20*15*1.6 mm^3. The proposed antenna is ideally suited for ISM band WiMAX and WLAN applications. For bandwidth enhancement, a rectangular cut, a step below an oval patch is used and a partial ground structure is used to improve reflection co-efficient parameters (S_{11}).

Index Terms: Wideband antenna, ISM band, WLAN/WiMAX applications, Partial ground structure.

1. Introduction

In the present era, modular designs, broadband, and reduced-size antennas that support numerous network applications simultaneously are in a growing market. Designers may be capable to use those same antennas to build communications connectivity. The IEEE 802.11b/g/5.15 GHz standard covers a range of frequencies from 2.4 to 2.484 GHz. The WiMAX spectrum spans 5.825 GHz (IEEE 802.11a) to 5.825 GHz (IEEE 802.11b) (IEEE 802.11b). These frequencies fall between 2.4 and 2.68 GHz/3.39 and 3.70 GHz/5.24 and 5.84 GHz range. The high-impedance microstrip antenna will be necessary for radiocommunication devices [1]. Due to their less cost, less weight, and better concert, microstrip antennas promise a better choice in modern wireless communication systems. Such antennas have typically inadequate in their pertinency due to their narrow bandwidth. These devices' impedance bandwidth (IBW) could be augmented by varying the shape of the radiating patch by etching slots and adding rectangular steps of varying sizes [2,7]. The recently shaped defective ground structure could be cast-off to supplement a solid ground plane in patch antennas to boost impedance bandwidth [8,9]. A defective ground plane has the benefit of minimizing the system's size and allowing the activation of additional resonance bands [10]. Because of the huge trend of wireless communications, hand-held devices now require low-profile, small, and wide-band antennas that can perform across many frequency groups, minimizing the need for distinct antennas for different applications. Microstrip patch antennas are in a momentous market for wireless infrastructures [11]. Future radiocommunication systems would necessitate structures with broad-band capability in highly changing environments [12]. For sustaining a wide range of necessities, including personal communication, home, vehicle, and workplace networking system. The radiocommunication market has prolonged intensely, and request for the ISM band, WLAN, and WiMAX is growing day by day. The receiver/Transmitter is a crucial constituent in performance, reliability, and size, it must meet three sets of requirements at the same time [13].

i) Dimensional appearances (compact size, lightweight, flexibility to official platform, and consumer); ii) Electronics efficiency (wide bandwidth, radiation qualities, high performance, design flexibility, and diversification applicability) iii) Production constraints (cheap price, reliability, packing competencies). The radio receiver's performance must not be affected by the surrounding environment, such as the social body, and the proposal must gratify fallout security and safety requirements. Radiocommunication communications continue on the way to grow at a rapid rate in the domains of cellular phones, wireless Internet, and wireless home networking. The IEEE 802.11 communication standard is responsible for defining wireless system ethics, including wireless local area networks (WLAN, WiMAX) [14]. The most essential innovations are present in the ISM bands from 2.4–2.4945 GHz to 5.15–5.936 GHz [15]. For example, WLANs that are currently the quickest and most reliable (for example, IEEE 802.11a [16]) operates in the 5–6 GHz frequency range, allowing for steady high-speed communication between all electronic gazettes like portable computers, personal organizers, and other wireless digital utilization [17]. In projected research, a diverse small broadband oval patch antenna is developed for 5 to 6 GHz ISM band, WLAN, and WiMAX applications. Because it can operate between 4.9 and 6.7 GHz, the suggested antenna is well-suited for the suggested solutions. The range of frequency for this antenna is 5.16–5.836 GHz, which covers the full ISM band. This micro-printed microstrip antenna is ideal for biomedical engineering and medical device installation.

2. Proposed Antenna Structure

The recommended antenna construction is demonstrated in Fig 1. The proposed antenna is designed by commercially available FR-4 substrate with relative permittivity of value 4.4. The dimensions of the base area are 20*15 mm^2. The excitement started with 50 Ω thick microstrip feed with a length width and height of 8*1.5*1.6 mm^3. An oval shape radiator patch and a rectangular step below the radiator are used in this study to enhance bandwidth and make the antenna appropriate for all 5-6 GHz applications by covering the entire spectrum. The estimated surface current distribution at various sampling frequencies of 5 - 6 GHz is represented in Fig .2. to validate broadband performance. The strong surface current occurs through both the oval-shaped and rectangular slots, as seen in Fig .2. (a). The first resonant mode of 5 GHz is seen to be produced by the oval shape and rectangular strip. The strong surface current is scattered over the oval patch, step, slot, and ground plane for the sampling frequency of 6 GHz, as illustrated in Fig 2(b, c).

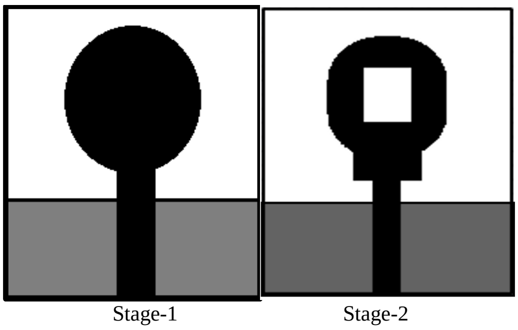

Fig. 1. Stages (Stage-1, 2) of the projected oval shape patch antenna

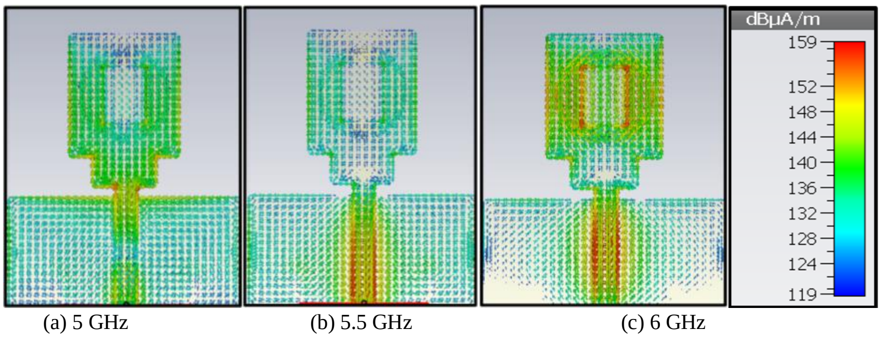

Fig. 2. Current spreading at various frequencies (5, 5.5, 6 GHz) of the projected antenna design.

Table 1. Design specifications of projected antenna

Parameters	Values in mm
Fr-4 substrate with relative permittivity (Ɛ) 4.4	15* 20* 1.6
Oval shape radiator patch	7* 8
Rectangular slot on radiator patch	3* 6
Rectangular step below radiator patch	3*2
50 Ω microstrip feed fine	1.5* 8
Partial ground plane	15*7
Edge cut of radiator patch	2

Fig.3. displays the projected S_{11} parameters for several antenna structure configurations, no cut and no step, (no cut, through step), (no cut, including step), and (with slot and step below patch). In the initial instances antenna runs between 1.3 and 3.5 GHz, encompassing the bottom half of the ultra-wideband as described by the Federal Communications & Commission (FCC). The addition of a rectangular step below the patch in the second situation allows the operational bandwidth to be obtained by increasing the higher frequency. The frequency range of the projected antenna is 1.5 to 4.0 GHz. The rectangular cut in the radiator allows the frequency band to be adjusted in the projected direction of higher frequencies in the third scenario. This amplifies both the lower and upper frequencies, allowing the antenna to operate between 2.9 and 4.6 GHz, thus covering the maximum spectrum.

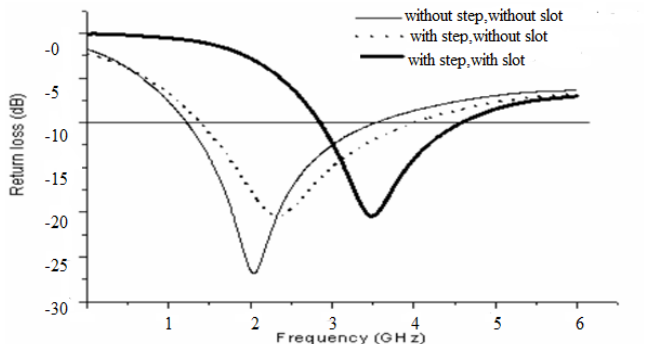

Fig. 3. Simulated (CST) S11 for different parameters

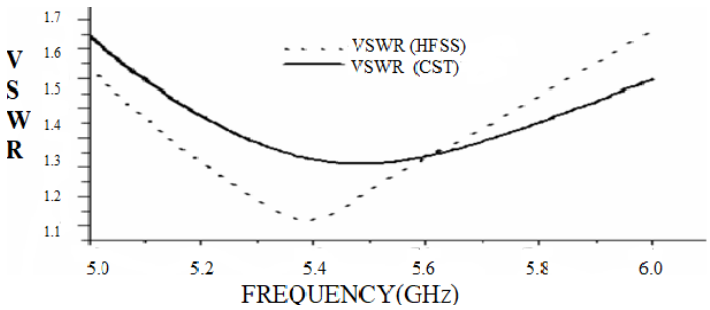

Fig. 4. VSWR (Voltage standing wave ratio) for projected antenna design

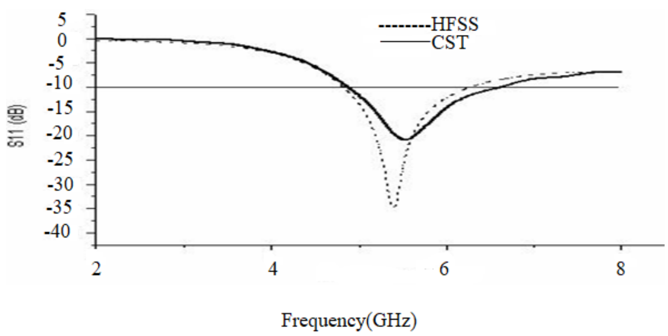

Fig. 5. Simulated return loss with both software (HFSS & CST)

Fig.5. depicts an oval-slotted patch antenna's estimated return loss (S11). The bandwidth of the suggested antenna for return loss (S_{11}) is 4.7 to 6.1 GHz with a high-frequency structure simulator and 4.91 to 6.61 GHz computer simulator technology (CST) studio suite 2018 version, which covers the whole 5-6 GHz range. The HFSS and CST results are very similar.

With the popular frequency range of 5-6 GHz, developed antenna gratifies the VSWR necessity of loss less than 2., as shown in Fig. 4. The impedance bandwidth (IBW) of planar monopole antennas is affected by multiple factors, along with the radiator element's size and the ground plane's size. This study focuses on the effects of the rectangular step's length and width and variations in length of partial ground plane. It may demonstrate using this broadband antenna's return loss(S11).

3. Effect on Variations of step length (L_{step}) by Changing Parameters

The S_{11} parameter was simulated for various step lengths as shown in Fig.6. The lower-edge frequency remains unchanged as the step length increases, while the topmost frequency rises. The appropriate step length is L step=2mm.

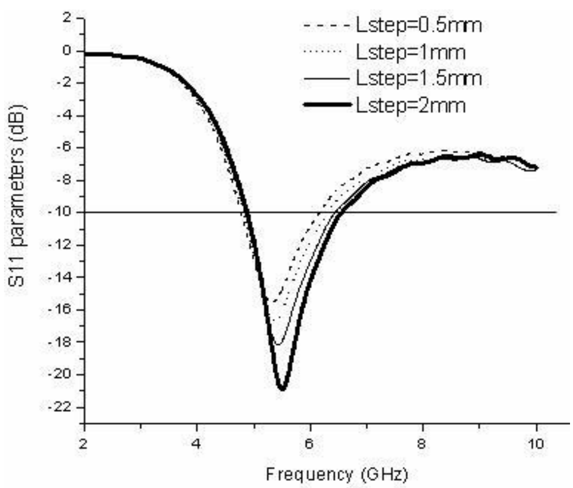

Fig. 6. Simulated results S_{11} parameters for changed values of step length (L step)

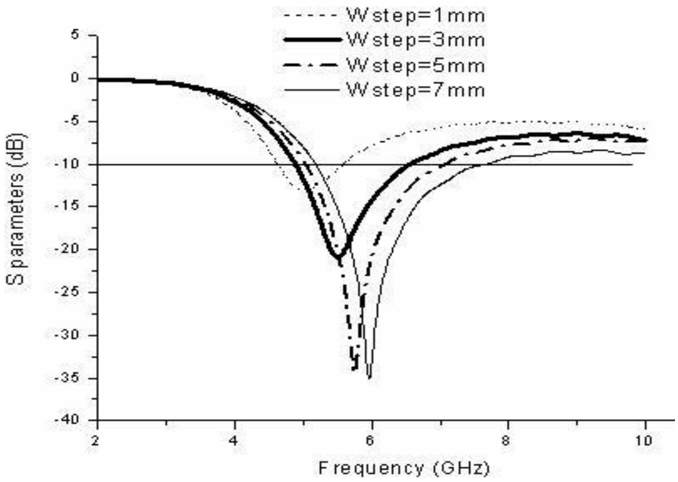

Fig. 7. Simulated results S_{11} parameters for changed values of step width (W step)

4. Effects of Variations on Step width (W Step) by Changing Parameters

Fig.7. shows the S_{11} parameters for several step width values. The width of the rectangular step appears to significantly impact the bandwidth. W_{step}=3mm is employed in this study to achieve a 5-6 GHz operational bandwidth.

4.1 Properties on variations of partial ground plane length (L_g) by changing parameters

The difference in values of S_{11} parameters is function of partial ground plane scope could be seen in Fig. 8. As the partial ground plane length is increased, lower and upper frequencies would also shift on the way to right and bandwidth will also shift towards upper frequencies. The optimized partial ground plane length is set at 7mm using the ideal settings described overhead.

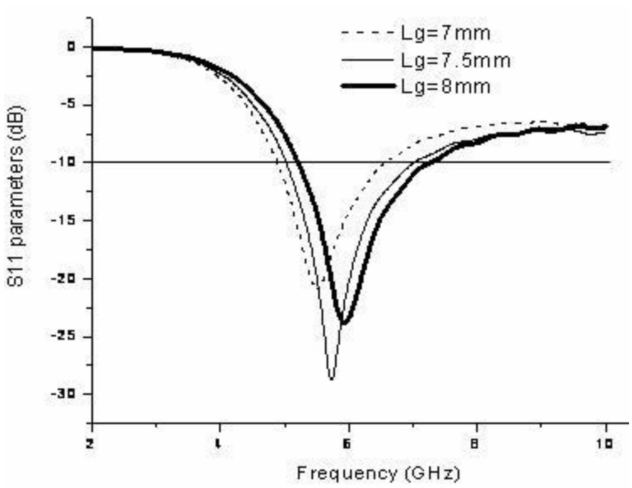

Fig. 8. Simulated S_{11} parameters for the changed values of ground plane length

The replicated radiation patterns at 5.25, 5.55, and 5.85 GHz are plotted in Figs 9-11. The proposed antenna's radiation patterns are essentially omnidirectional over the operational bandwidth, analogous to a distinctive monopole antenna.

4.2 The simulated Radiation pattern of the projected antenna

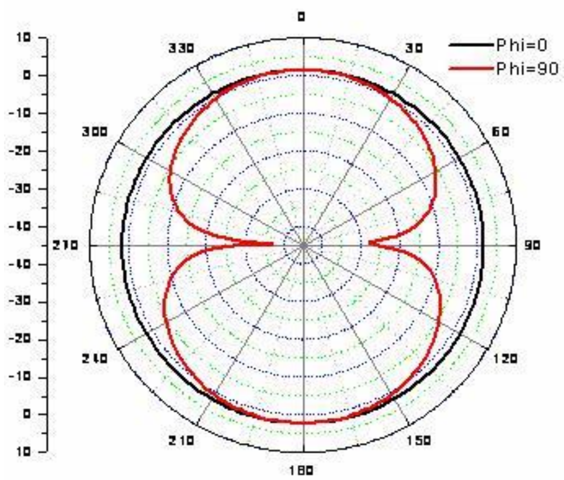

Fig.9. Radiation pattern of projected antenna at frequency 5.25 GHz

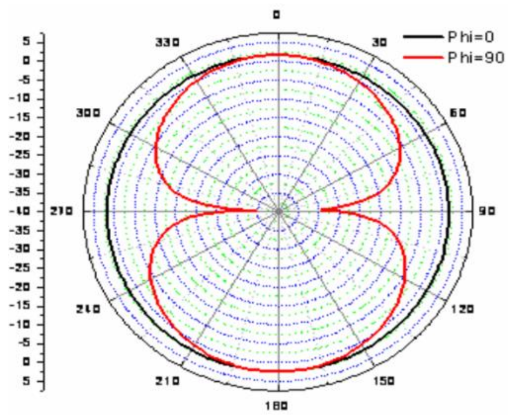

Fig. 10. Radiation pattern of projected antenna at frequency 5.55 GHz

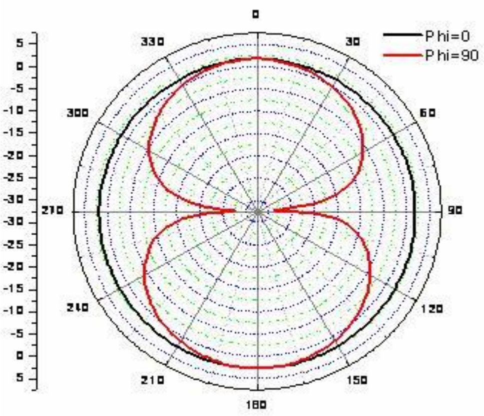

Fig. 11. Radiation pattern of projected antenna at frequency 5.85 GHz

The greatest improvement over the entire frequency range is represented in fig.12. Due to its high gain, the projected antenna design is well suited for 5 to 6 GHz ISM, WLAN, and WiMAX applications.

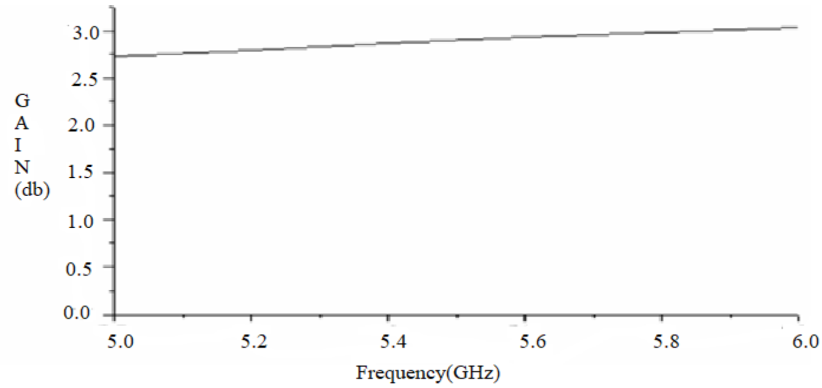

Fig. 12. The Gain of projected antenna in dB over frequency band 5-6 GHz

5. Conclusion

The characteristics of oval shape rectangular microstrip antenna impedance are enhanced by using a rectangular step and slot in the radiator patch element of the antenna. The results of the high-frequency structure simulator (HFSS) and computer simulation technology (CST) microwave studio experiments shown above are honestly equal. Due to its compact size and outstanding performance, the suggested rectangular slotted patch and step below the radiator could be a promising choice for widely used 5 to 6 GHz and broadband applications (ISM band, WLAN, WiMAX). The frequency range for VSWR 2 is between 4.8 and 6.5 GHz. Over its operational band, the antenna's emission pattern and maximum gain are detailed.

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Anil Kumar Gautam was born in the Indian city of Noida in the state of Uttar Pradesh. In 1999 and 2007, he got his B.E. in Electronics & Communication Engineering from Kumaon Engineering College in Almora, India, and his Ph.D. in Electronic Engineering from the Indian Institute of Technology, Banaras Hindu University in Varanasi, India. He started as an Assistant Professor in the Department of Electronics and Communication Engineering at G. B. Pant Engineering College (GBPEC) in Pauri, Garhwal, India, in 2000, and has been an Associate Professor there since 2009. Dr. Gautam is a member of GBPEC, Pauri's Board of Study (BOS), the Academic Council, and numerous other academic bodies. Dr. Gautam is also a member of the HNB Garhwal Central University's Board of Trustees and the Uttarakhand Technical University's Board of Trustees in Dehradun, India. He is a member of the IEEE (United States) as well as several other technical associations. He also serves on the editorial boards of IEEE Transactions on Antennas and Propagation, IEEE Antenna and Wave Propagation Letters, IET Microwaves, Antennas & Propagation, Personal and Wireless Communication, Springer, International Journal of Electronics, International Journal of Microwave and Wireless Technologies, International Journal of Antenna and Propagation, and others. His main research interests include Active Microstrip Antenna Design and Modelling, Microstrip Antennas with Defective Ground Structure, Ultra-wide Bandwidth Antennas, and reconfigurable antennas, such as reconfiguration antenna arrays and circularly polarised antennas.

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