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REGULAR ARTICLE

Design and Analysis of a Notched Super Wide Band Antenna for Wireless Communication

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A corner truncated square shaped monopole microstrip patch antenna with slotted spur line in feeding path is designed and analyzed in this article. The proposed antenna operates in a super wide band range of 1.9 to 25.7 GHz with a rejected band of 8.7 to 10.6 GHz. The fractional bandwidth of 172.4 % is achieved with this design. The optimum dimension of the spur line has been taken for generation of the notched band at desired frequency. Due to the rejected band, the designed antenna will be working for any applications within the super wideband range except amateur radio operation and amateur satellite operations; thus, it shows the novelty of the paper as no such antenna design for this application has been reported earlier. The antenna is very small in size with the overall electrical dimension of $0.13\lambda \times 0.11\lambda \times 0.0096\lambda$, where λ is the wavelength of the lowest operating frequency 1.9 GHz. The complete size of the antenna is only $21 \times 18 \times 1.524$ mm^3. The peak realized gain of the antenna is 5 dBi within the operating band and the gain at the notched frequency is minimized to – 6.5 dBi due to the spur line. The antenna is designed and simulated in commercially available software (HFSS).

Keywords: Rectangular microstrip antenna, Compactness, U-slot.

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1. INTRODUCTION

Wireless communication is becoming increasingly important in today's communication-driven world. Taking this into account, the Federal Communication Commission (FCC) first approved the protocols in February 2002 for the commercial usage of ultra-wide band (UWB) [1-2]. In April of the same year, the FCC formally sanctioned the utilization of technology operating within a frequency range of 3.1 to 10.6 gigahertz without the requirement of a license. [3]. In essence, UWB is a communication technology that sends a lot of signals at low energy levels over a shorter distance [4-5]. In order to prevent interference from wireless applications operating in the 3.1 to 10.6 GHz band, short-range, low-power transmission is employed. Wide-band radio spectrum is used by UWB to convey data. In addition, its hardware system is simpler than that of a traditional wireless communication system. The most promising technology for the future is this one, which may be used for high data rate transmission in many applications such as indoor location systems, high accuracy radar, imaging, sensor data gathering, and so on. This technique is becoming more and more popular among eminent academicians, industrialists, and researchers because of its distinctive qualities.

Effective UWB communication implementation requires well designed antennas with the necessary features; in fact, these antennas are an essential component of effective UWB communication. The researchers find it difficult to develop an antenna that can suitably match the requirements, such as compact size, high gain, omnidirectional radiation pattern, wide impedance bandwidth, and so on, because of the greater frequency spectrum, which is around 7500 MHz. Numerous studies have been conducted in this area and have suggested a number of antennas for efficient UWB communication [6-11]. A Multi Input Multi Output (MIMO) antenna structure with four monopoles for operating in the range of 2-12 GHz has been presented in [6]. A modified elliptical monopole antenna with slot in the ground plane has been designed for UWB operation [7]. In [8], a 'Heart' shaped antenna design has been proposed for broadband applications. Some different shape of antenna has been designed for wideband applications [9-10]. A design of dual layered hexagonal shaped microstrip antenna with EBG structure has been reported in [11]. The proposed antenna resonates in the range of 5.1 – 19.7 GHz having highest gain of 5.7 dBi. For future cognitive radio applications, geometry of an antenna composed of two semi circles has been constructed [12], where the fractional of 5.7 GHz has

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been obtained. A miniaturized super wideband antenna with bandwidth of 164 % has been designed by three step staircase structure in both side of the patch [13]. However, the printed monopole antenna (PMA), with its distinctive qualities of compact size, lightweight, low profile, and ease of fabrication has provided the exact solution for this communication. Despite advancements in PMA design for UWB, impedance matching, gain, and bandwidth are the main factors that might impact an antenna's performance. Several notable design strategies have been integrated into PMA to address this issue. These techniques include cutting slots on the patch, slot on the ground, using parasitic elements, using EBG etc.

Interference remains the biggest obstacle that UWB applications encounter, despite constant advancements in antenna design technology. Different researchers have documented several strategies and tactics to get around this interference. A modified rectangular patch with three rectangular and a circular slot etched on it has been presented in the letter [14]. Additionally, by cutting two rectangular slits on the ground, the antenna has achieved fractional bandwidth of 120 %. A PIN diode has been used in the circular slot for obtaining the notched band. A differential coplanar waveguide fed tapered slotted UWB antenna has been proposed in [15] where the operating band is 2.78 – 12.3 GHz. One pair of half wavelength slits and stubs inside the circular patch and tapered slot have been introduced to get the notched band from 5.2 – 6 GHz. Some other basic monopole and Vivaldi structure of microstrip antenna have been reported in the literatures [16-18], where slots over the radiating metal were used to achieve the notched band. To block the interference of the populated X band frequencies with the antenna operating band another filtering circuit is required which may make the system complicated. To overcome this complexity, the notch band antenna is the right solution. Circular and hexagonal shaped microstrip monopole antennas are presented in the literature where U shaped slot and mushroom EBG have been used to achieve single notched band within the ultra-wideband response [19-20].

In this article, a square shaped monopole microstrip antenna is illustrated for super wideband application within the range of 1.9 GHz to 25.7 GHz with a rejected band 8.7 to 10.6 GHz. The square antenna is modified by cutting four corner slots, a ground notch and a spur line in the feeding path. The corner slots and the ground notch produce the super wide bandwidth, and the spur line generates the desired notched band. The complete size of the antenna is only $21 \times 18 \times 1.524$ mm^3. The maximum realized gain of the antenna is 5 dBi and gain for the notched band is – 6.5 dBi. The designed antenna may be working for super wideband wireless communication with band rejection for amateur radio operation and amateur satellite operations; thus, it shows the novelty of the paper as no such antenna design for this application has been reported earlier.

2. DESIGN DESCRIPTION OF THE ANTENNA

The antenna is designed on Arlon AD300A substrate with $\varepsilon_r = 3$ and the thickness is 1.524 mm. In the evolution of the designed antenna a defected ground square patch has been taken as reference antenna at step 1. To increase the bandwidth four corner slots have been incorporated on the patch in step 2. Furthermore, a rectangular notch has been placed in the ground plane just beneath the feeding line. This modification indicates in step 3. To achieve notch band a spur line has been introduced on the feeding line which is demonstrated as step 4 in the antenna evolution process. The step-by-step modification of the proposed design is shown in Fig. 1.

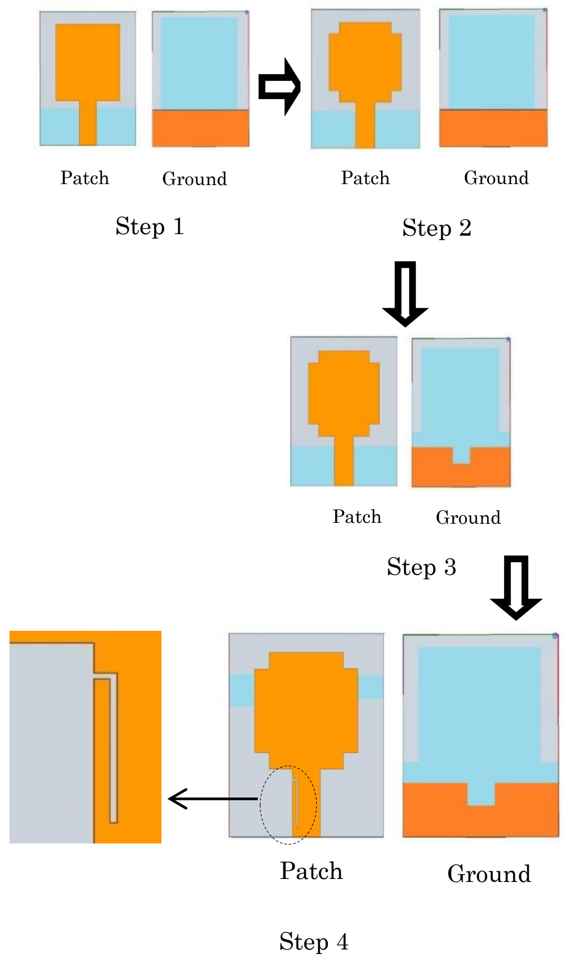

Fig. 1 – Evolution of the antenna

The different S_{11} responses for every steps of the designed antenna are graphically illustrated in Fig. 2. The proposed antenna with all dimensions is pictured in Figs. 3-5. The optimum values of the dimensions are given after parametric studies in Table 1. Fig. 3 represents the front view the proposed antenna. The back side view of the antenna is depicted in Fig. 4 and the dimension for the spur line is shown in Fig. 5 where it is magnified for better understanding.

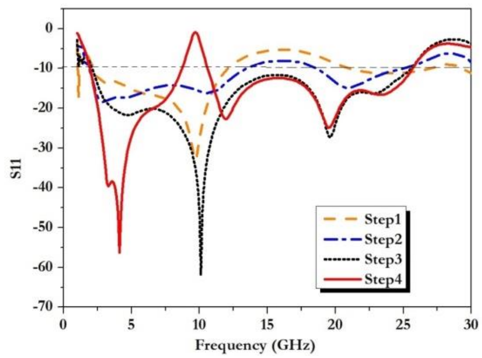

Fig. 2 – S_{11} responses for evolution of designed antenna

Table 1 – Optimum values of the dimension for the designed antenna

Dimension	Values (mm)	Dimension	Values (mm)
W	18	W_f	3.2
L	21	W_g	5.5
W_p	12	W_n	3.1
L_p	12	L_n	2.1
S_1	1.7	W_s	0.6
S_2	1.7	L_s	5
L_f	7	W_{gap}	0.2

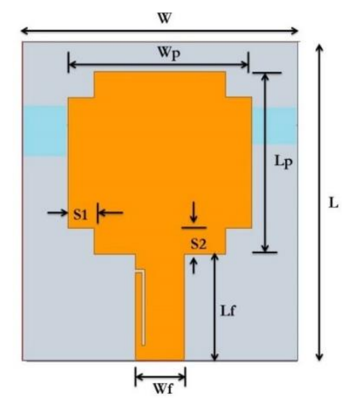

Fig. 3 – Front view of proposed antenna with dimensions

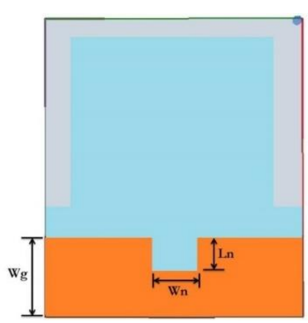

Fig. 4 – Back view of proposed antenna with dimensions

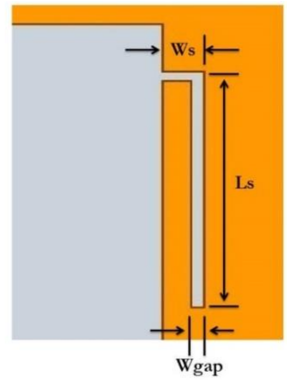

Fig. 5 – Magnified view of spur line with dimensions

3. SIMULATED RESULT ANALYSIS OF THE DESIGNED ANTENNA

The reference square monopole antenna resonates in the frequency range of 2.18 to 12.08 GHz. All the optimum dimensions of the reference antenna have been taken such that the antenna operates in ultra-wideband range. To increase the bandwidth further, four corner slots have been trimmed and the modified antenna resonates in the frequency range of 1.86 to 13.49 GHz. A super wideband response of the antenna, spanning a range from 2.13 to 25.54 GHz, has been realized through the implementation of a rectangular notch on the ground plane. To get the notch band finally a spur line has been added in the feeding path of the antenna and hence the proposed antenna produces a super wideband in the frequency range of 1.9 to 25.7 GHz with a rejected band of 8.7 to 10.6 GHz. The S_{11} graph of the proposed antenna is demonstrated in Fig. 6. All the simulated results are given in Table 2.

Table 2 – Simulated results of the designed antenna

Antenna	Frequency Range (GHz)	Notched Band (GHz)
Square Patch (Reference) – Step 1	2.18 – 12.08	–
With corner slots – Step 2	1.86 – 13.49	–
With corner slots and ground notch – Step 3	2.13 – 25.54	–
With corner slots, ground notch and spur line (Proposed) – Step 4	1.9 – 25.7	8.7 – 10.6

The peak realized gain of the antenna is 5 dBi and gain for the notched band is – 6.5 dBi. The simulated gain and efficiency graph is illustrated in Fig. 7. From the Fig. 7, it is noticed that the efficiency has also been decreased at notched frequency. The absolute E plane and H plane radiation patterns at 9.6 GHz i.e. at notch frequency and at 12 GHz frequency i.e. one of the pass band frequencies are shown in Figs. 8-11.

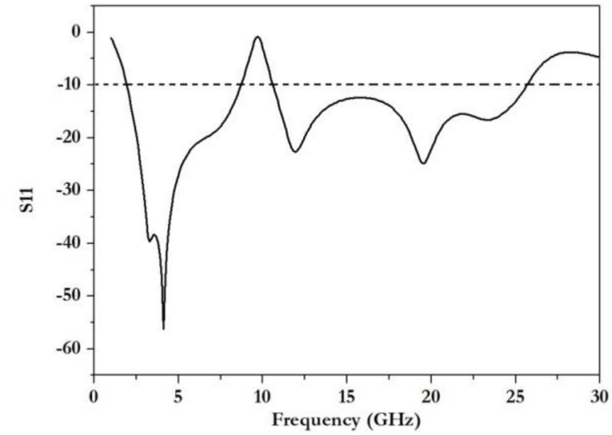

Fig. 6 – Simulated S_{11} of the proposed antenna

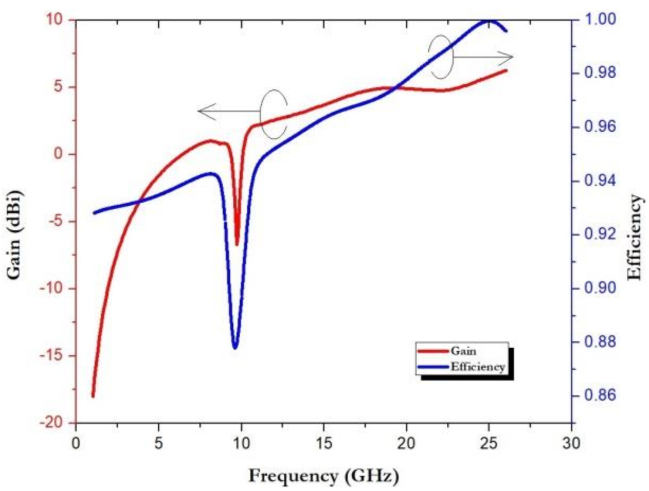

Fig. 7 – Frequency vs gain and efficiency plot of the antenna

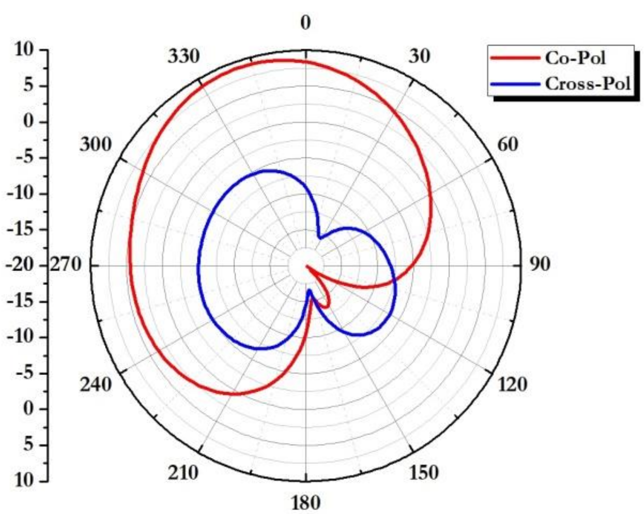

Fig. 8 – Absolute *E* Plane radiation pattern at 9.6 GHz (Notch Frequency)

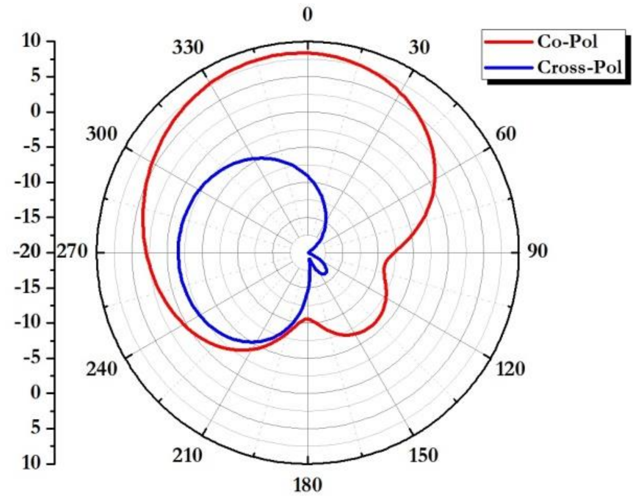

Fig. 9 – Absolute *H* Plane radiation pattern at 9.6 GHz (Notch Frequency)

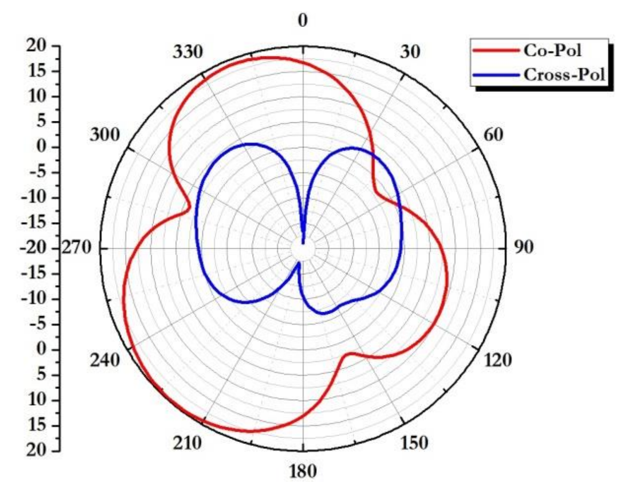

Fig. 10 – Absolute *E* Plane radiation pattern at 12 GHz

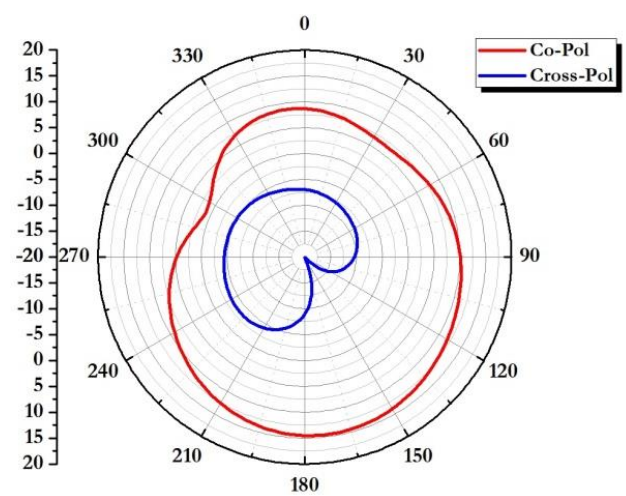

Fig. 11 – Absolute *H* Plane radiation pattern at 12 GHz

In Figs. 8-11 both the co-pol and cross-pol radiation patterns are plotted. It is obvious that the radiation intensity has been significantly decreased for the notched band frequency of 9.6 GHz with respect to one of the pass band frequencies 12 GHz.

4. CONCLUSION

A miniaturized monopole microstrip antenna has been designed for super wideband applications with a notched band property and the design concept along with the simulated results are presented in this literature. The proposed antenna operates in a super wide band range of 1.9 GHz to 25.7 GHz with a rejected band of 8.7 GHz to 10.6 GHz. The fractional bandwidth of 172.4 % is achieved with this design. Due to the rejected band, the designed antenna will be working for any applications within the super wideband range except amateur radio operation and amateur satellite operations. Reduction of the circuit complexity to block the populated X band frequencies has been successfully achieved by designing the notched band antenna. The maximum isolation of 11.5 dB between the pass band and the notch band has been obtained.

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Проєктування та аналіз надширокосмугової антени з вирізаним діапазоном для бездротового зв'язку

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У цій статті представлено мікросмужкову антену типу монополь з квадратним патчем та зрізаними кутами, яка містить вузьку щілинну структуру (spur line) у лінії живлення. Запропонована антена працює в надширокосмуговому (Super Wide Band, SWB) діапазоні 1.9–25.7 ГГц з відсіченим (notched) діапазоном 8.7–10.6 ГГц, що забезпечує фракційну смугу пропускання 172.4%. Вибір оптимальних розмірів spur line дозволяє точно сформувати зону відсічення у зазначеному частотному діапазоні. Завдяки цьому антена може бути використана в будь-яких системах SWB-зв'язку, окрім радіоаматорських застосувань у зоні виключення — що є новизною цієї розробки, адже раніше такі рішення не повідомлялись. Антена має дуже компактні розміри: Електричний розмір: $0.13\lambda \times 0.11\lambda \times 0.0096\lambda$, де λ – довжина хвилі для 1.9 ГГц, Фізичні розміри: $21 \times 18 \times 1.524$ мм^3. Максимальний реалізований коефіцієнт підсилення у робочому діапазоні становить 5 дБі, а на частотах в зоні відсічення він зменшується до – 6.5 дБі завдяки дії spur line. Проєктування та моделювання виконано в середовищі HFSS (High Frequency Structure Simulator).

Ключові слова: Прямокутна мікросмужкова антена, Компактність, U-слот, Надширокосмугова антена, Вирізаний діапазон.