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PATCH AND GROUND PLANE SLOTS EFFECT ON THE RECTANGULAR PATCH MICROSTRIP UWB ANTENNA BANDWIDTH PERFORMANCE

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Abstract—In this paper, the impact of patch and ground plane slots on the bandwidth performance of a microstrip UWB antenna is presented. Our reference antenna is a microstrip feeding type monopole feature with a rectangular patch and a partial ground plane. In order to evaluate the characteristics of the reference antenna bandwidth, two separate slot types (right-angle triangular and rectangular) have been inserted into the patch and a single slot configuration like a rectangular is also inserted into the partial ground plane on the backside of the feed line to the appropriate. The influence on the bandwidth characteristics of single and multiple slot cases is analyzed using the HFSS simulator. Based on the slot configurations, the simulation results verify that the antenna bandwidth can be improved.

Keywords— **Microstrip UWB antenna, Ground plane slot, Patch slots, Bandwidth enhancement.**

I. INTRODUCTION

Since the low power, widespread bandwidth of 3.1-10.6 GHz has been adopted by FCC for ultra-wideband (UWB) services, several works have centered on designing and modifying antennas within this band over the past 15 years, taking into account low price, small size, broad impedance bandwidth, omnidirectional characteristics, and easy manufacturing. For this purpose, in addition to being a good candidate for this work, the small size monopole microstrip antenna could be used for many communication systems such as radar application, location and tracking systems, ad-hoc systems, and many others. Microstrip antenna has recently been used by applying several antenna structure modifications for ultra-wideband technology.

For the investigation of impedance matching, the technique for extending the bandwidth of ultra-wideband antennas by using ground slot techniques of different shapes and configurations such as rectangular, partly circular triangular, and hexagonal under the backside of the radiator feed line is commonly considered. The effect of the slots on impedance bandwidth assessment, radiation pattern characteristics, output gain, and radiation efficiency was realized by the simulation test results. Among the other proposed slot configurations, a hexagonal slot on the ground surface achieved the best fractional bandwidth improvement of 136.08 percent for a magnitude of S11 < -10 dB [1]. The authors tested a pacman-shaped antenna with a square ground cut back under the top edge of the feed line to enhance the impedance bandwidth efficiency in [2]. A good impedance bandwidth function between 2.9-15 GHz is given by the proposed antenna and has an omnidirectional radiation pattern. In [3], by changing the proposed square antenna structure, the authors implemented a special small square slotted antenna with a variable band-stop characteristic for UWB purposes, the adjustment was rendered by adding two configurations of G-shaped slots in the ground and a T-shaped ring slot at the square radiating patch. Both simulation and measurement assessment showed that the proposed antenna can activate efficiently with VSWR less than 2 in the frequency range of 2.95 - 15.65 GHz and has rejection bands around 5.13GHz and 5.91 GHz. In [4], a circular patch antenna was examined and adjusted by correctly cutting the diagonal edges of the ground plane and inserting a T-shaped slot.

The antenna acquired a wider bandwidth of 3-12.62 GHz via this process (123.32 %) than the standard FCC 3.1-10.6 GHz bandwidth (109.45 %). To increase the bandwidth properties receiving modification from 117 percent to 175%, several works with distinct ground cutting have been investigated such as the M-shaped configuration proposed in [5], other works used U-shaped structures [6,7], while the inverted T-shaped antenna used [8] was investigated with a modified fork-shaped monopole antenna with two L-shaped etched slots [9], In addition, W-shaped, good results on the ground plane are provided by Π-shaped and boat-shaped slot configurations [10], beak-shaped structure [11], right C-shaped slot produced a wide bandwidth with two band removal features for the 96 GHz WLAN operating range [12], various square shapes linked to each other [13], and circular grooves [14]. The monopole antenna was modified by adding rectangular and arc-shopped slots on the ground to prevent electromagnetic interference between UWB and narrowband systems, resulting in an increased input coefficient of reflection and bandwidth [15]. In [16], a simple microstrip rectangular antenna with a bandwidth of 133.33 % and a gain of 1.5-4.8 dB for UWB applications was designed using a defective ground structure (DGS) with various places of the extra patch in the ground. A microstrip antenna design based on the defective ground structure (DGS) and horizontal patch gap (HPG) was developed in [17] to achieve bandwidth and improved performance goals. The antenna's gain was 2.8 dBi and its bandwidth was 764.4 MHz. Raviteja et al. [18] studied the use of U and Quad L-shaped slots, as well as L-shaped DGS and U-shaped dual parasitic components. The gain of this antenna is 7.2 dB, and the bandwidth is 1.40 GHz. A modern semi-circular ultra wide-band antenna [19] with a broad bandwidth of 130.3 % from 3.16 to 15 GHz and gain ranging from 4.9 dB to 10.9 dB was presented for broadband applications. D. Gopi1 et al. [20] described a simple low-profile monopole circular-shaped patch antenna based on a defective ground structure for ultra-wideband applications. The impedance bandwidth of the antenna ranges between 2.5 and 10.6 GHz. The two resonant frequencies have gains of 8.4 dBi and 8.2 dBi, respectively. In [21], a rectangular microstrip patch antenna was structured for gain enhancement using the air gap method. The gain is improved from 6.907 dB to 9.179 dB based on the simulation results. A miniaturized enlarged bandwidth UWB microstrip antenna was intended using metamaterial (MTM) double-side planar periodic structures in [22]. The antenna has a 3.2 to 23.9 GHz large bandwidth and a 6.2 dB maximum gain at 8.7 GHz. A compact high-gain (MHG) ultra-wideband (UWB) unidirectional monopole antenna with a defective ground structure (DGS) for ultra-wideband applications was explained by J. Vijayalakshmi et al. [23]. This antenna has a high gain of 7.20 dB, 95 % efficiency, and a frequency range of 3.2 to 10.6 GHz. K. G. Tan et al. [24] developed a reconfigured UWB antenna with a gain boost for wireless applications based on a FR4 substrate. The results show that with a maximum gain of more than 6.5 dB, an impedance bandwidth ranging from 2.2 GHz to more than 12 GHz, or 138 % fractional bandwidth, can be observed. A.F. Darweesh and G.O. Yetkin [25] proposed a miniaturized size ultra-wideband microstrip antenna depending on a metamaterial array for UWB applications using computer simulation technology (CST) software. The results demonstrated an enhanced bandwidth of 2.6 GHz – 20 GHz with a gain of 5.6 dB. T. Sarkar et al. [26] exhibited a new and insightful study of a low-profile ultra-wide-band (UWB) microstrip antenna for DS-UWB applications. According to the simulation results, the impedance bandwidth is 109 %. In [27], a compact mace-shaped ground plane modified circular patch antenna was designed for ultra-wideband applications. According to simulation results, the peak gain and fractional bandwidth of this antenna are 3.2 dB and 118 % (3.1 to 12.13 GHz), respectively. The authors suggested a tiny stepped slot antenna for ultra-wideband (UWB) applications in [28]. The antenna's impedance bandwidth ranged from 3.05 to more than 12 GHz. In [29], researchers looked into the notched-band characteristics of a very small ultra-wideband (UWB) slot antenna with three L-shaped slots. Based on the current simulation results, the antenna has an impedance bandwidth ranging from 2.65 to 11.05 GHz. A modified patch and electromagnetic band gap (EBG) structure were used to control the center frequency and notched bandwidth of a compact ultra-wideband (UWB) antenna [30]. The study found that an improved bandwidth of 3.1 - 12.5 GHz and a maximum gain of 4.5 dBi could be obtained. A compact UWB planar antenna with a corrugated ladder ground plane for a wide range of applications was discussed in [31]. The antenna has a maximum gain of 3.5 dB and impedance bandwidth of 130.4 % (2.4 – 11.4 GHz).

The effect of patch and ground slots on the performance of bandwidth for a given ultra-wideband (UWB) microstrip antenna is discussed in this article. The investigated antenna is a conventional monopole UWB antenna with a simple rectangular patch and partially ground plane and a type of microstrip transmission feed line. In order to evaluate the proper dimensions of the proposed antenna, a parametric analysis is performed. To determine the bandwidth characteristics of the reference antenna (conventional antenna), the patch has been inserted into two separate slot configurations (triangular and rectangular) and a single slot configuration, including a rectangular one, has also been inserted into the partial ground plane at the back of the upper edge of the feed line. It studies the impact of single and multiple slots on the characteristics of bandwidth.

The remaining parts of this work are designed as: the proposed antenna design and structure are developed in section II. In section III, the simulation results are explained in detail. Finally, the conclusion segment has section IV.

II. ANTENNA DESIGN AND GEOMETRICAL STRUCTURE

As a reference antenna, a conventional microstrip UWB antenna with a monopole-like feature has been used. It is made up of a copper rectangular patch placed on the top side of a FR4-epoxy substrate (PCB) with a relative permittivity (r) of 4.4 and a dielectric tangent loss of 0.02 and fed by a standard microstrip feed line with a characteristic impedance of 50 Ω. As shown in Fig.1, the bottom side of the PCB has a partial ground plane of copper. The dimensions of the different antenna components are listed in Table 1.

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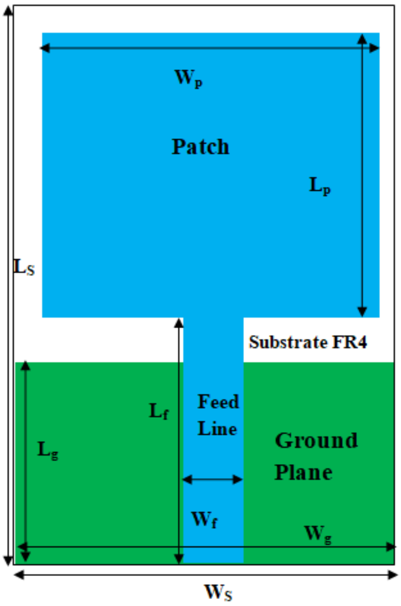

Fig. 1: The geometrical structure of the reference microstrip UWB antenna

Table 1: Proper dimensions of the components of the reference microstrip UWB antenna

Antenna's component	**Dimension (mm)**
Substrate	Ws=20, Ls=30
Patch	Wp=18,Lp=14
Microstrip feed line	W_f=2, L_f=15
Partial ground plane	W_g=20, L_g=14
Thickness	h =0.8
Relative permittivity, ε_r	4.4

To analyze the bandwidth performance of the investigated antenna in the UWB frequency range, multiple slot configuration cases are carved on the patch and single slot configuration cases are cut on the partial ground plane on the back of the feed line (slot antenna), as illustrated in Fig. 2. In this slot case, various configurations are used, such as right-angle triangular and rectangular configurations. The dimensions of the slots are listed in Table 2.

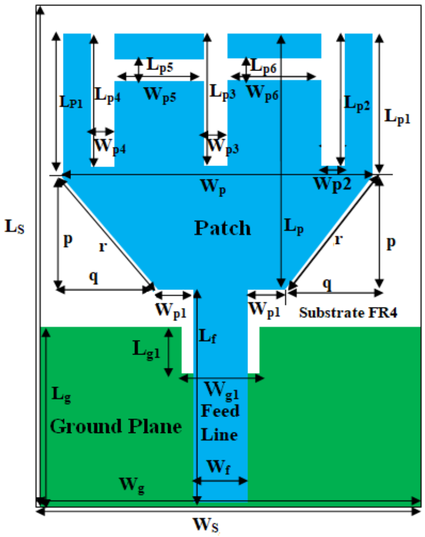

Fig. 2: Multiple slot configurations (right-angle triangular and rectangular) on the patch and single slot configuration (rectangular) on the ground plane in the feed line back side.

Table 2: Dimensions of different configurations of the slots

Slot Configurations	**Dimension (mm)**
Rectangular and Right-Angle Triangular	W_{p1}=2,L_{p1}=8,W_{g1}=2, L_{g1}=3, W_{p2}=W_{p3}=W_{p4}=0.5, L_{p2}=L_{p3}=L_{p4}=7, W_{p5}=W_{p6}=6.5, L_{p5}=L_{p6}=0.5, p = q= 6, r = 8.48

III. RESULTS AND DISCUSSIONS

A simulation analysis using HFSS simulator software has been carried out to study the various antenna bandwidth performances. The frequency range over which a given return loss can be controlled is referred to as bandwidth (also known as impedance bandwidth). Because return loss measures how much power the antenna accepts from the transmission line, the impedance of the antenna needs to match the impedance of the transmission line for maximum power transfer. After all, the impedance of the antenna varies with frequency, leading to a limited range over which the antenna can be matched to the transmission line. This range is measured by bandwidth. It is usually associated with a specific return loss or VSWR value. The simulated return loss of the reference antenna (without slot) and with various slot configurations, including triangular and rectangular, is shown in Fig. 3 and summarized in Table 3. The conventional UWB antenna has a bandwidth of 4.25 GHz (3.05-7.25 GHz) with a return loss < -10 dB. However, the bandwidth of the antenna is enhanced by applying various slot configurations such as right-angle triangular and rectangular. It is improved to 6.40 GHz by embedding right-angle triangular slots in the lower corners of the patch and rectangular slots into the top edge of the patch, which are between 2.95 GHz and 9.35 GHz. Two independent slot configurations, such as right-angle triangular-rectangular, are inserted into the patch, and a single configuration, such as a rectangular slot, is also inserted into the partial ground plane, which is known as a proposed antenna. By incorporating right-angle triangular-rectangular slots into the patch and a single rectangular slot into the partial ground plane, the bandwidth is increased to 19.75 GHz (2.95 GHz to 22.7 GHz). This is approximately 4.70 times wider than the bandwidth of the reference antenna. This antenna is suitable for a wide range of wireless applications, including X band, C-band, Ku band, S-band, STM band, WiMAX, WiFi, WLAN, radio astronomy, military communications, communications and sensors, positioning and monitoring, radar, and satellite communication. From the above discussion, it is obvious that the bandwidth of the proposed antenna rather than the conventional patch antenna (reference patch antenna) has improved significantly. We note that the antenna is a good candidate to fulfill the criteria for UWB bandwidth.

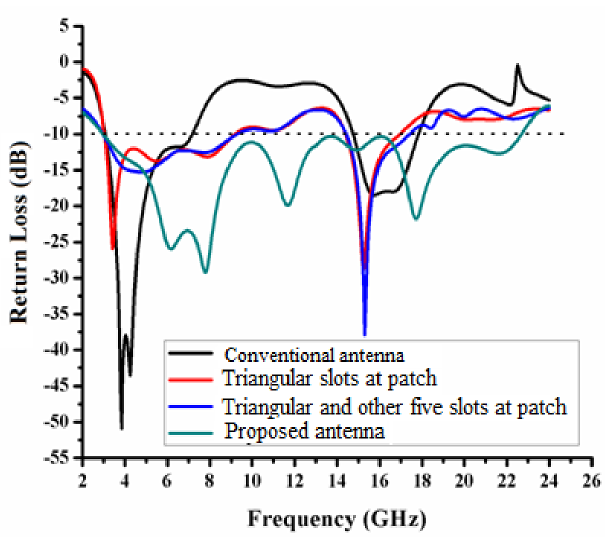

Fig. 3: Simulated return loss of the conventional antenna (reference antenna) without slots and with various slots.

Table 3: Characteristics of the bandwidth for the reference antenna without slots and for the proposed antennas with various slot configurations

Antenna Name	Return Loss (dB)	Resonance Frequency (GHz)	Operating Bandwidth (GHz)	Bandwidth (GHz)
Reference antenna (without slots)	-50.94	3.85	3.05-7.25	4.20
Antenna with right-angle triangular slots	-25.34	3.45	2.95-9.35	6.40
Antenna with right-angle triangular and five rectangular slots	-37.97	15.30	2.95-9.35	6.40
Proposed antenna (right-angle triangular and rectangular slots)	-29.25	7.75	2.95-22.70	19.75

IV. CONCLUSION

In this article, conventional and slot antennas have been successfully designed, and the effect of patch and ground slots on the performance of rectangular patch microstrip UWB antenna bandwidth has been investigated. A rectangular patch with a microstrip feed line and partially ground plane is the reference monopole antenna (conventional antenna). In order to determine the correct dimensions of the proposed antenna, a parametric analysis is used. In order to change the conventional antenna bandwidth characteristics, two distinct slot shapes (right-angle triangular and rectangular) have been embedded into the patch and one slot configuration, such as rectangular, has been added into the partial ground plane on the rear end of the feed line. The implications of single and multiple slots on the characteristics of bandwidth have been studied. The final results of the simulation show that it is possible to increase the antenna bandwidth depending on the configurations of the slots and the number of slots inserted.

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