UWB Slot Antenna with Band-Stop Operation by Using H-Shaped Parasitic Structures for UWB Applications

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Abstract ─ A novel ultra wideband (UWB) printed slot antenna with band-notched performance is designed and manufactured. In order to increase the impedance bandwidth of the slot antenna, we use a rectangular slot with an H-shaped parasitic structure inside the rectangular slot on the feed-line that with this structure UWB frequency range can be achieved. Additionally, by using a square ring radiating stub with a rotated H-shaped parasitic structure inside the square ring, a frequency band-stop performance has been obtained. The designed antenna has a small size of 20 × 20 mm^2 while showing the radiation performance in the frequency band of 2.97 GHz to over 12.39 GHz with a band rejection performance in the frequency band of 5.01 GHz to 5.98 GHz. Simulated and experimental results obtained for this antenna show that it exhibits good radiation behavior within the UWB frequency range.

Index Terms - Microstrip slot antenna, H-shaped parasitic structure, and ultra wideband application.

I. INTRODUCTION

In UWB communication systems, one of key issues is the design of a compact antenna while providing wideband characteristic over the whole operating band. Consequently, a number of printed microstrip with different geometries have been experimentally characterized [1-2], and automatic design methods have been developed to achieve the optimum planar shape [3]. Moreover, other strategies to improve the impedance bandwidth have been investigated [4-5].

The federal communication commission (FCC)'s allocation of the frequency range 3.1 GHz – 10.6 GHz for UWB systems and it will cause interference to the existing wireless communication systems, such as, the wireless local area network (WLAN) operating in 5.15 GHz – 5.35 GHz and 5.725 GHz – 5.825 GHz bands, so the UWB antenna with a single band-stop performance is required [6-11]. The easiest and most common technique is embedding a narrow slot into the radiating patch of the antenna and change the current flows on it, as used in [8, 9]. In [8, 9] different shapes of the slots (i.e., square ring and folded trapezoid) are used to obtain the band notch function. Single and multiple band notch functions are achieved by cutting single and multiple half-wavelength U-shaped slits in the radiating patch. On the other hand, another method to avoid this frequency interference is the use of reconfigurable antennas. The reconfigurable structure provides switchable band notch characteristic and whenever there is no coexisting system, the antenna can use the whole UWB spectrum. In [10] RF MEMS are used for notching the WLAN band while in [11] PIN diodes are used for the same reason.

A novel and compact microstrip-fed slot antenna with additional resonance and band-notched characteristics for UWB applications has been presented. This letter focuses on a rectangular slot antenna for UWB applications, which combines the square ring radiating stub approach with a rotated H-shaped parasitic structure inside the square ring, and the microstrip feed-line with a rectangular slot with an H-shaped parasitic structure inside the rectangular slot that achieves a fractional bandwidth of more than 120 %. In the proposed structure, first by cutting a rectangular slot with an H-shaped parasitic structure inside the rectangular slot on the

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microstrip feed-line, additional resonance is excited and hence, much wider impedance bandwidth can be produced, especially at the higher frequencies. In order to generate a single band-notch function, for the first time, we use a rotated H-shaped parasitic structure inside the square ring radiating stub. In the slot antenna design, by reducing the antenna size, the impedance matching at lower frequencies becomes poor and the bandwidth is degraded [3-4]. The distinctive point of the proposed antenna is that although it has small size with respect to the antennas introduced in [2-5], (43 % smaller than the antenna in [4]), it has wider impedance bandwidth in the frequency band of 2.97 GHz to 12.39 GHz with a rejection bands around 5.01 GHz – 5.98 GHz, which has a frequency bandwidth increment of 13 % with respect to the previous similar antenna [8-11], and also, the impedance matching at lower frequencies is very well obtained. Unlike other band-notched UWB antennas reported in the literature to date [6-9], this structure has an ordinary square radiating stub configuration. Simulated and measured results are presented to validate the usefulness of the proposed antenna structure for UWB applications.

II. ANTENNA DESIGN

The presented slot antenna fed by a 50 Ω microstrip line is shown in Fig. 1, which is printed on a FR4 substrate of thickness 0.8 mm, permittivity 4.4, and loss tangent 0.018. The basic antenna structure consists of a square radiating stub, a 50 Ω microstrip feed-line, and a ground plane with a rectangular slot. The square radiating stub has a width W. The radiating stub is connected to a feed line of width W_f and length L_f, as shown in Fig. 1. On the other side of the substrate, a conducting ground plane with a rectangular slot is placed. The proposed antenna is connected to a 50 Ω SMA connector for signal transmission.

In this study, based on electromagnet coupling theory (ECT), the H-shaped parasitic structure inside the rectangular slot in the microstrip feed-line is playing an important role in the broadband characteristics of this antenna, because it can adjust the electromagnetic coupling effects between the feed line and the parasitic element, and improves its impedance bandwidth without any cost of size or expense [5]. As illustrated in Fig. 1, the rotated H-shaped parasitic structure is placed inside the square ring radiating patch and is also symmetrical with respect to the longitudinal direction. The rotated H-shaped parasitic structure perturbs the resonant response and also acts as a parasitic half-wave resonant structure electrically coupled to the square ring radiating stub [7]. At the notch frequency, the current flows are more dominant around the parasitic element, and they are oppositely directed between the parasitic element and the square ring radiating stub [8-9]. As a result, the desired high attenuation near the notch frequency can be produced.

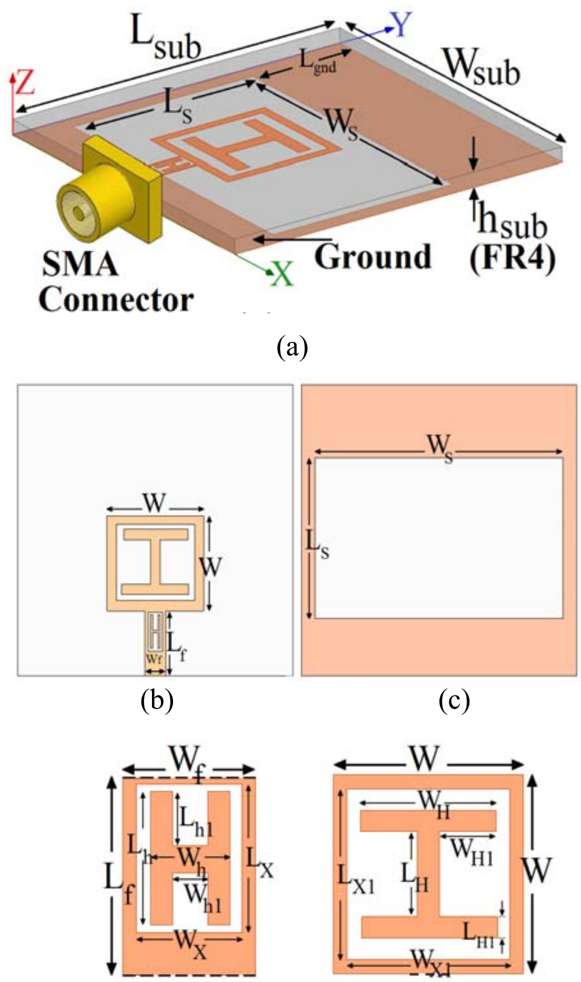


Fig. 1. (a) Geometry of the proposed square slot antenna, (b) top layer, (c) bottom layer, (d) a rectangular slot with an H-shaped parasitic structure on the feed-line, and (e) rotated H-shaped parasitic structure inside the square ring radiating stub.

In this work, we start by choosing the aperture length L_S. We have a lot of flexibility in choosing this parameter. The length of the aperture mostly affects the antenna bandwidth. As L_S decreases, so does the antenna BW and vice versa. Next step, we have to determine the aperture width W_S. The aperture width is approximately $\lambda_S/2$, where λ_S is the slot wavelength that depends on a number of parameters such as the slot width as well as the thickness and dielectric constant of the substrate on which the slot is fabricated. The last and final step in the design is to choose the length of the radiating patch W. A good starting point is to choose it to be equal to $W = \lambda_m/4$, where λ_m is the guided wavelength in the microstrip line [4]. The important step in the design is to choose L_{notch} (the length of the filter) and $L_{resonance}$ (the length of the resonator). L_{notch} is set to band-stop resonate at $0.5\lambda_{notch}$, where $L_{notch1}= L_{X1}+W_{X1}+2L_{H1}+L_H$, λ_{notch} correspond to notched band frequency wavelength (5.5 GHz), and $L_{resonance}$ is set to resonate at $0.25\lambda_{resonance}$, where $L_{resonance}=L_h+2L_{h1}+Wh$, $\lambda_{resonance}$ correspond to third resonance frequency wavelength (10.2 GHz).

The optimal dimensions of the designed antenna are as follows: W_{sub} = 20 mm, L_{sub} = 20 mm, h_{sub} = 0.8 mm, W_S = 18 mm, L_S = 11 mm, W_f = 1.5 mm, L_f = 4 mm, W = 7 mm, W_X = 1.1 mm, L_X = 2.8 mm, W_{X1} = 6 mm, L_{X1} = 6 mm, W_h = 0.7 mm, L_h = 2.4 mm, W_{h1} = 0.3 mm, L_{h1} = 1 mm, W_H = 5 mm, L_H = 4.5 mm, W_{H1} = 2.25 mm, L_{H1} = 0.5 mm, and L_{gnd} = 6 mm.

III. RESULTS AND DISCUSSIONS

In this section, the planar slot antenna with various design parameters were constructed, and the numerical and experimental results of the input impedance and radiation characteristics are presented and discussed. The parameters of this proposed antenna are studied by changing one parameter at a time and fixing the others. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [12].

Figure 2 shows the structure of various antennas used for simulation studies. VSWR characteristics for ordinary square slot antenna (Fig. 2 (a)), with a rectangular slot with an H-shaped parasitic structure inside the rectangular slot on the feed-line (Fig. 2 (b)), and the proposed antenna structure (Fig. 2 (c)) are compared in Fig 3.

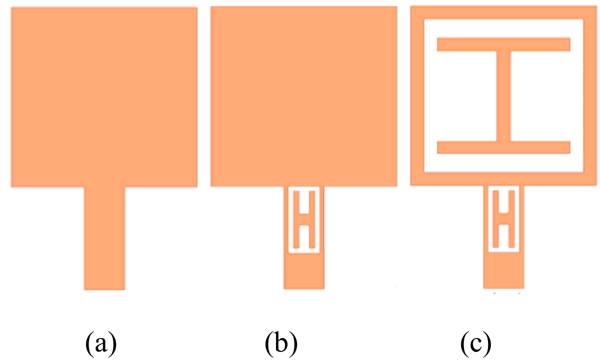


Fig. 2. Radiating stub and microsrtip feed-line of (a) the ordinary slot antenna, (b) the antenna with a rectangular slot with an H-shaped parasitic structure on the microstrip feed-line, and (c) the proposed antenna.

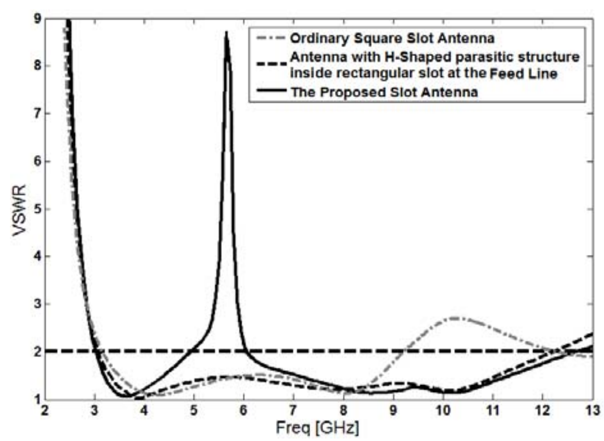


Fig. 3. VSWR characteristics for the various antenna structures shown in Fig. 2.

It is found that by inserting the rectangular slot with an H-shaped parasitic structure inside the rectangular slot on the feed-line, the antenna can create the third resonant frequency at 10.2 GHz and hence the impedance bandwidth is effectively improved at the upper frequency [13]. Also as shown in Fig. 3, in this structure, the rotated H-shaped parasitic is used in order to generate the frequency band-stop performance. Also the input impedance of the various slot antenna structures that shown in Fig. 2, on a Smith chart is shown in Fig. 4.

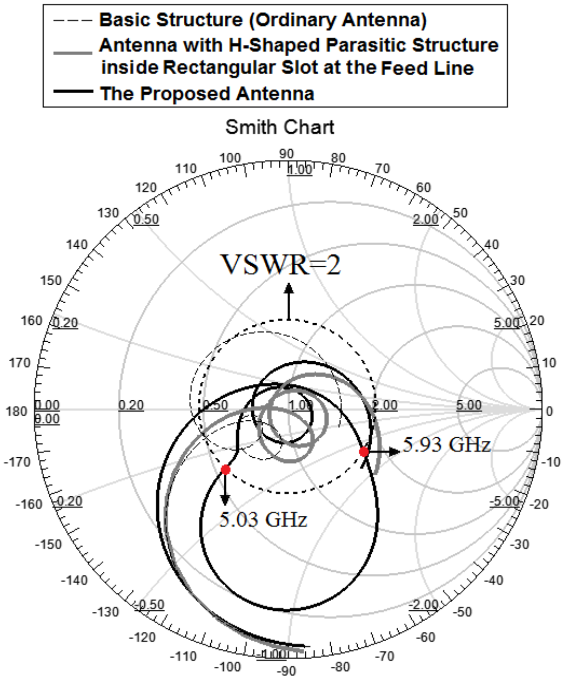
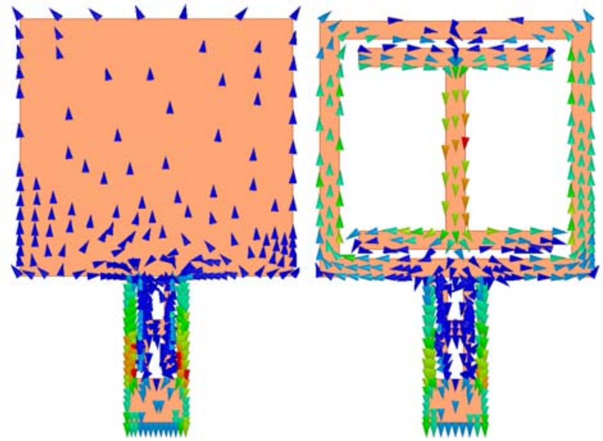


Fig. 4. The simulated input impedance on a Smith chart of the various slot antenna structures shown in Fig. 2.

In order to understand the phenomenon behind this new additional resonance performance, the simulated current distribution on the radiating patch and feed-line for the square antenna with a rectangular slot with an H-shaped parasitic structure inside the rectangular slot on the feed-line at new resonance frequency (10.2 GHz) is presented in Fig. 5 (a). It can be observed in Fig. 5 (a) that the current concentrated on the edges of the interior and exterior of the H-shaped parasitic structure at 10.2 GHz. Therefore, the antenna impedance changes at these frequencies due to the resonant properties of the H-shaped parasitic structure. In addition, by inserting the rotated H-shaped parasitic structure the band notch performance is created [14-15]. It can be observed on Fig. 5 (b) that the current concentrated on the edges of the interior and exterior of the rotated H-shaped parasitic structure inside the square ring radiating stub at the notch frequency (5.5 GHz). This figure shows that the electrical current for the new resonance frequency (5.5 GHz) does change direction along the coupled rotated H-shaped parasitic structure, due to the band notch properties of the proposed structure.



(a) (b)

Fig. 5. Simulated surface current distributions on the radiating stub and microstrip feed-line for (a) the square antenna with a rectangular slot with an H-shaped parasitic structure on the microstrip feed-line antenna at 10.2 GHz and (b) the proposed antenna at 5.5 GHz.

The proposed antenna with optimal design was built and tested. Figure 6 shows the measured and simulated VSWR characteristics of the proposed antenna. The fabricated antenna satisfies the VSWR < 2 requirement from 2.97 GHz to over 12.39 GHz with a band rejection performance in the frequency band of 5.01 GHz to 5.98 GHz. As shown in Fig. 6, there exists a discrepancy between measured data and the simulated results this could be due to the effect of the SMA port. In order to confirm the accurate VSWR characteristics for the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully.

Figure 7 shows the measured radiation patterns including the co-polarization and cross-polarization in the *H*-plane (*x-z* plane) and *E*-plane (*y-z* plane). The main purpose of the radiation patterns is to demonstrate that the antenna actually radiates over a wide frequency band. It can be seen that the radiation patterns in *x-z* plane are nearly omni-directional for the three frequencies [16].

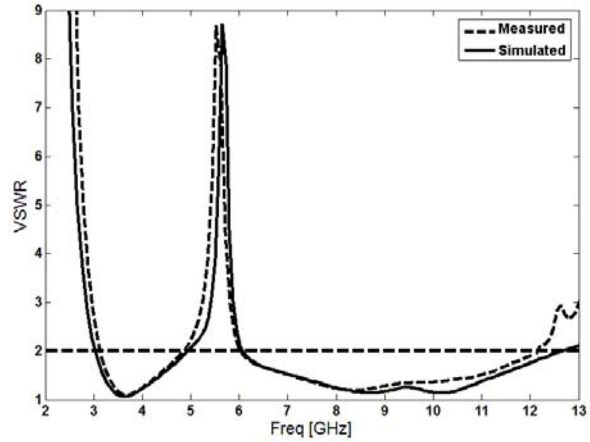


Fig. 6. Measured and simulated VSWR characteristics for the proposed antenna.

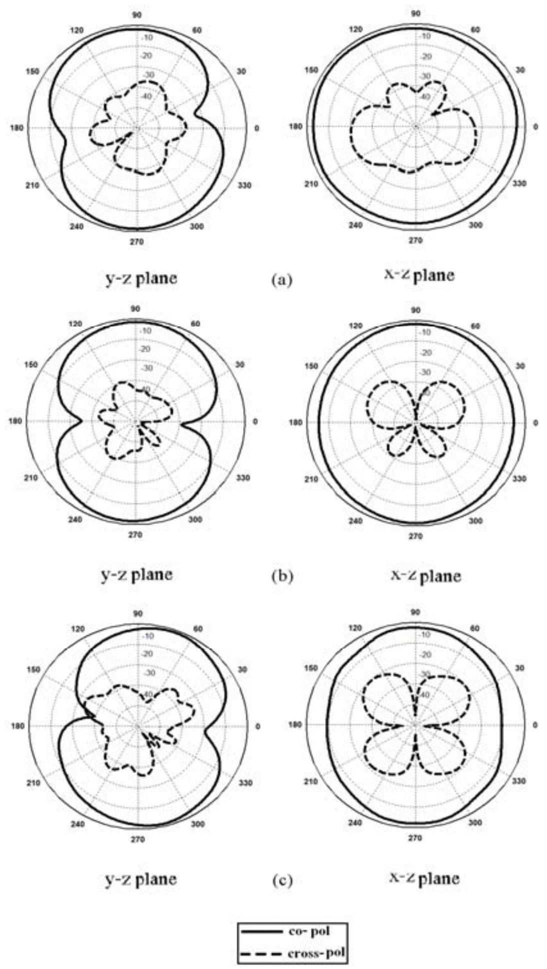


Fig. 7. Measured radiation patterns of the proposed antenna, (a) 4 GHz, (b) 8 GHz, and (c) 12.2 GHz.

IV. CONCLUSION

In this letter, a novel compact printed slot antenna (PSA) has been proposed for UWB applications. The fabricated antenna satisfies the VSWR < 2 requirement from 2.97 GHz to over 12.39 GHz with a band rejection performance in the frequency band of 5.01 GHz to 5.98 GHz. By cutting a rectangular slot with an H-shaped parasitic structure inside the slot on the microstrip feed-line, additional resonance is excited and hence, much wider impedance bandwidth can be produced, especially at the higher band, also by inserting a rotated H-shaped parasitic structure inside the square ring radiating stub the band notch performance is generated. The proposed antenna has a simple configuration and is easy to fabricate. Experimental results show that the proposed antenna could be a good candidate for UWB applications.

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