Band-Notched compact rectangular ring Antenna using Triple Ω-Shaped Structures for UWB Systems

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Abstract **—** In this letter, a new ultra wideband monopole antenna with frequency band-stop function is designed and manufactured. The antenna contains a rectangular ring radiating patch and a partial ground. In the structure, by etching a Ω-shaped slot on the ground plane, extra resonance is excited and therefore more extended impedance bandwidth can be achieved. In order to create band-rejected function a Ω-shaped sleeve into the rectangular ring patch and an inverted Ω-shaped slot on it and feed-line are used. The measured results depicts that the antenna is able to cover the bandwidth from 2.6 to 10.4 GHz for VSWR≤ 2 excluding the rejected bands from 3.1 to 3.8 GHz and from 5.0 to 6.0 GHz. Acceptable VSWR and radiation pattern characteristics are earned on the frequency band of interest.

Index Terms **—** UWB antenna; notch band, stop band.

I. INTRODUCTION

Ultra-wideband (UWB) technologies have attracted noticeable attention since the FCC allocated the frequency band of 3.1 GHz to 10.6 GHz for commercial use in 2002. Different sorts of antennas have been investigated for UWB systems, and among which printed monopole antennas have been widely regarded as an excellent candidate, since they are very compact in size and can be easily integrated with RF circuits and devices [1-2]. However, over the released UWB operation bandwidth, there are some narrow bands occupied by the existing wireless systems. Most notable among them are the Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX), which operate with the center frequencies of 5.2 GHz (5150-5350 MHz), 5.8 GHz (5725-5825 MHz) for WLAN and 3.5GHz (3400-3690 MHz), 5.5 GHz (5250-5850 MHz) bands for WiMAX. Therefore, the potential electromagnetic interference (EMI) problems should be paid much attention. Recently, numerous band-notched UWB antennas have been investigated and reported, which can reject the certain band within the ultra-wide passband without mounting additional bandstop filters [3-9]. Although, the set of these antennas are designed to generate only one notched frequency band so that just one narrow band of disturbance can be eliminated. Consequently, these antennas are still open to other potential disturbance from neighboring RF systems. In this paper, a monopole antenna with band-notched characteristics for UWB applications is proposed. By utilizing a series of new techniques on radiating patch and ground plane, wide band and band-notched UWB characteristics can be resulted. The practical prototype was implemented and tested, and the measured results show a suitable agreement with the simulated ones. Details of the antenna design and parameter study are presented and discussed as follows.

II. ANTENNA DESIGN

The geometry of the antenna is showed in Figure 1. The antenna is fabricated on a 22×15 mm2 FR4 substrate with thickness 1mm and relative permittivity εr = 4.4. The antenna contains a rectangular ring radiating patch and a partial ground. As shown in Figure 1, to obtain desirable impedance bandwidth, a Ω-shaped slot is etched from partial ground plane symmetrically and in order to achieve the lower notched band at centre frequency of 3.5GHz, a Ω-shaped sleeve is placed into rectangular ring radiating patch. On the other hand, to earn the upper stop band at center frequency of 5.5GHz, an inverted Ω-shaped slot is etched on both patch and feed-line. The radiating patch is connected to a 50-ohm microstrip line with width, length 1.9mm and 7.5mm, respectively. The whole antenna is optimized by the electromagnetic simulation software of Ansoft High Frequency Simulation Structure (HFSS) based on the finite element method (FEM) [10], and values of some optimized parameters are shown in Figure 1. The next section is related to the antenna design process and the effect of various parameters on VSWR.

III. ANTENNA PERFORMANCE AND DISCUSSION

In this section, the rectangular monopole 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 varying one parameter at a time and fixing the others. As shown in Figure 2, the simulated reflection coefficient loss characteristics for three antennas with different ground structures are presented. Regarding to it, Ant.1 (primary monopole square antenna) has an impedance bandwidth from 3.2 to 9.15 GHz, while Ant.2 with an inverted T-shaped slot on the ground plane increases the bandwidth from 3.15 to 9.6.

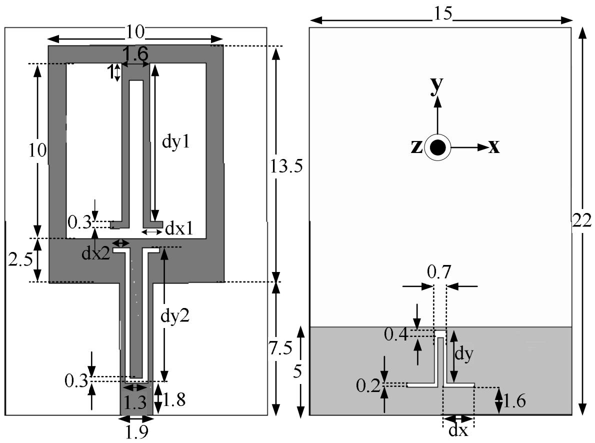

Fig. 1. Geometry of the proposed antenna (dx=1.8mm, dy=3mm, dx1=1.1mm, dy1=9mm ,dx2=1mm ,and dy2=7.7mm)

By replacing the Ω-shaped slot instead of the inverted T-shaped slot on the ground plane in Ant. 3, a considerable resonance is created at 10.4 GHz which improves impedance bandwidth from 3.15 to 10.7GHz. As far as Figure 3 is concerned, simulated reflection coefficient characteristics of the antenna are depicted for different values dx where dy is constant (dy=3mm). On the other hand, the effect of varying parameter dy on reflection coefficient characteristics where dx is constant (dx=1.8mm) has been studied in Figure 4.

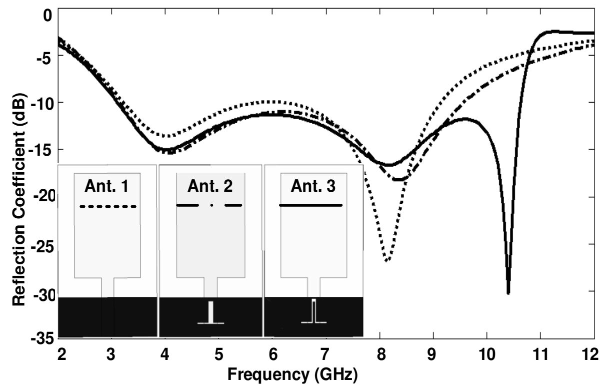

Fig. 2. The comparison of simulated reflection coefficient characteristics of the various antenna structures.

From Figure 3 can be concluded that the upper frequency of the impedance bandwidth is affected by using the Ω-shaped slot on the ground plane, and also by optimizing it, additional third resonant frequency is more excited. Meanwhile, the upper-edge frequency of the impedance bandwidth is decreased from 11.8 to 9.8GHz with increasing value dx from 1.0 to 2.2 mm. Therefore, the optimized dx is 1.8 mm.

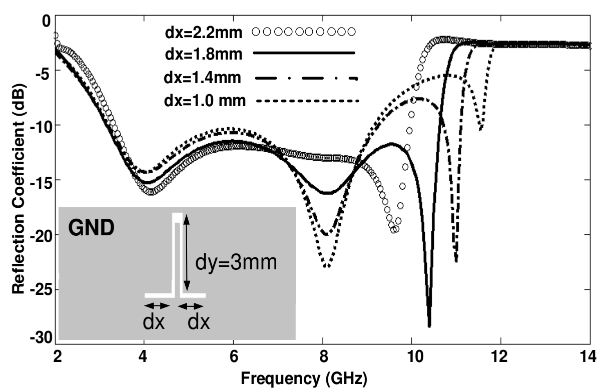

Fig. 3. Simulated reflection coefficient characteristics of the antenna with a Ω -shaped slot on the ground for different values of dx where dy is constant (dy=3mm).

It can be found out that the effect of dy at the upper-edge frequency of the impedance bandwidth is more than dx. With regard to Figure 4, the best value for dy is 3 mm. As mentioned before, to obtain an UWB antenna with notched band function, two new techniques are employed including the Ω-shaped sleeve into rectangular ring radiating patch and the inverted Ω-shaped slot on both patch and feed-line. The former for the lower notched band at center frequency 3.5 GHz, the latter for the upper notched band at center frequency 5.5 GHz. As illustrated in Figure 5, the VSWR characteristics for four different antenna structures indicating design procedure are compared to each other.

As it is apparent in Figure 5, Ant. I was optimized and it led to a desirable impedance bandwidth. With comparison Ant. II and III, by adding the Ω-shaped sleeve into rectangular ring radiating patch, firstly the bandwidth is improved and secondly the desirable lower notched band at center frequency of 3.5 GHz is produced. Furthermore, with etching an inverted Ω-shaped slot on both of the patch and feed-line in Ant. IV as compared to Ant. III, another notched band on the upper band at center frequency 5.5 GHz is appeared. There is an interesting point to note that two notched bands are exactly independent from each other which means that by emerging the second notched band, the first one has not been shifted.

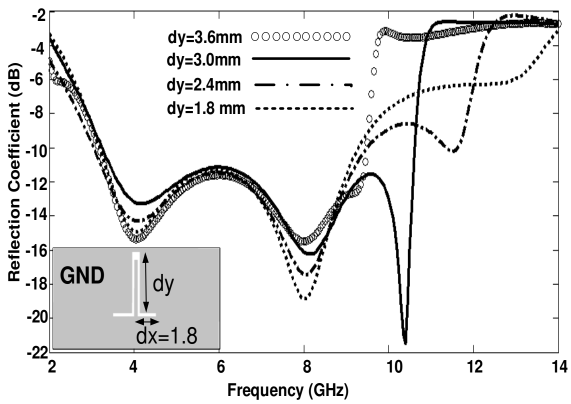

Fig. 4. Simulated reflection coefficient characteristics of the antenna with a Ω -shaped slot on the ground for different values dy where dx is constant (dx=1.8mm).

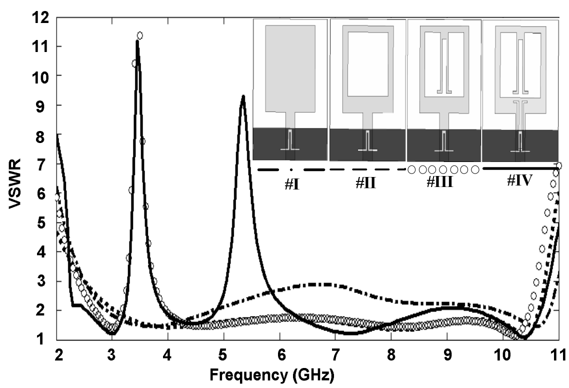

Fig. 5. The comparison of Simulated VSWR characteristics of the various antenna structures.

Figure 6 exhibits that Simulated VSWR characteristics of the antenna for different values of dx1 has a direct effect on the control of central frequency of the lower notched band. In other words, the center frequency is decreased from 3.8GHz to 2.8 GHz with increasing dx1 from 0.5mm to 2.9mm. Since by shifting the lower notched band, the upper notched band is nearly station, therefore two notched bands are controllable and independent. Regarding to desirable notched band (3.3-3.69), the best value of dx1 is 1.1mm.

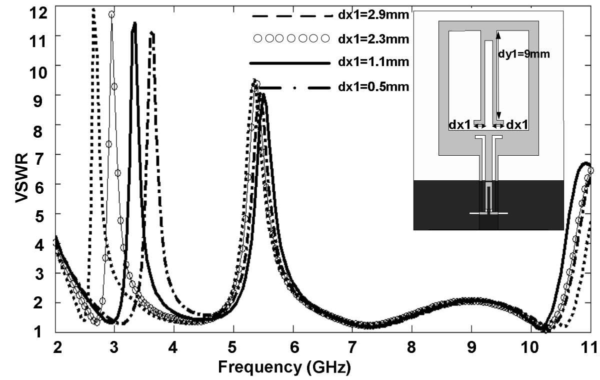

Fig. 6. Simulated VSWR characteristics of the antenna for different values of dx1 where value of dy1 is constant (dy1=9mm).

As mentioned before, to achieve notched band at center frequency 5.5GHz, an inverted Ω-shaped slot has been etched on both of the patch and feed-line. Figure 7 depicts the simulated band-rejected feature with varying dy2 where dx2 is constant (dx2=1mm). As shown in Figure 7, tuning the length of the slots can achieve a controllable center-rejected frequency range from 5 to 6 GHz for the second notched band. Figure 7 also demonstrates that dy2 is a key factor to control the rejected VSWR value. As length of dy2 of the slots increase from 5.7 to 8.7 mm, the central frequency of the notched band is varied from 7.2 to 4.8 GHz. The acceptable value of dy2 is 7.7mm.

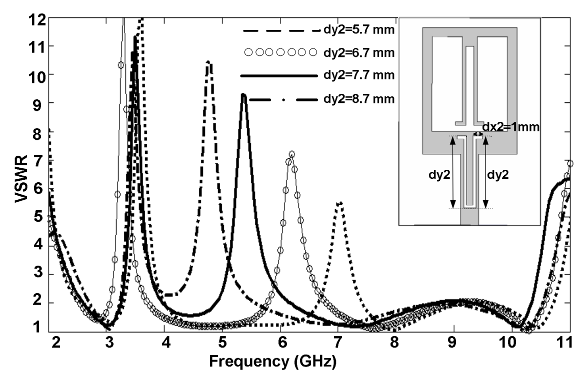

Fig. 7. Simulated VSWR characteristics of the antenna for different values of dy2 where value of dx2 is constant (dx2=1mm).

To understand the phenomenon behind this dual stop-band function, the simulated current distributions on the radiating patch at both 3.5 GHz and 5.5 GHz are depicted in Figure 8. It can be found out from Figure 8 that at frequency 3.5GHz the greatest current is concentrated at around of the Ω-shaped sleeve into rectangular ring radiating patch while at 5.5GHz it is focused at around the inverted Ω-shaped slot. All of them consequently end up the acceptable VSWR within both notched bands. This is apparent from Figure8 that the Ω-shaped sleeve and the inverted Ω-shaped slot are responsible for the first and second notch band, respectively. The proposed antenna has been implemented based on the dimensions presented in Figure 1. It also was tested in the Antenna Measurement Laboratory at Iran Telecommunication Research Center. The VSWR of the proposed antenna has been measured using an Agilent E8362B network analyzer in its full operational span (10 MHz-20 GHz). The simulated and measured VSWR of the fabricated antenna are also depicted in Figure 8. The fabricated antenna are able to cover impedance bandwidth from 2.6 to 10.4 GHz for VSWR≤ 2 with two notch bands around 3.1 to 3.8 GHz and from 5.0 to 6.0 GHz. As exhibited in Figure 8, there exists a discrepancy between measured data and the simulated results, and this could be due to the effect of the SMA port. The photo of fabricated antenna is apparent in Figure 9. To confirm the accurate reflection coefficient characteristics for the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully.

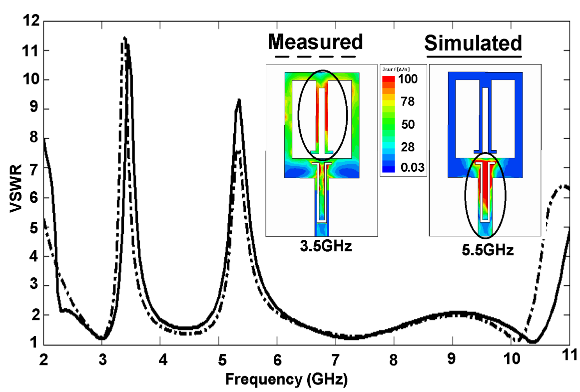

Fig. 8. Measured and simulated VSWR for the antenna and current distribution at both central frequencies of notched bands 3.5 and 5.5GHz.

Figure 10 illustrates the measured radiation patterns of the proposed antenna with notched bands at frequencies of 4.5, and 7 GHz in E-plane (yz-plane) and H-plane (xz-plane). It is distinctly revealed from the Figure that H-plane patterns are purely omni directional at all frequencies, while the E-plane patterns similarly exhibit the expected monopole-like behaviors. Figure 11 shows the measured maximum gain of the proposed antenna with and without notched band. A sharp decrease of maximum gain in the notched bands at both 3.5GHz and 5.5 GHz are shown. For other frequencies outside the notched frequency band, the antenna gain with the slot is similar to those without it.

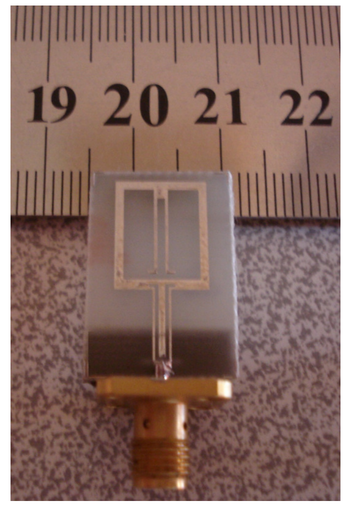

Fig. 9. Photograph of the fabricated antenna.

IV. CONCLUSION

A new ultra wideband monopole antenna with frequency band-stop function has been presented. The desired band-rejected property is achieved by embedding a Ω-shaped sleeve into a rectangular ring radiating patch and etching an inverted Ω-shaped slot on it. Experimental and measured results reveal the dual notched bands can be tuned flexibly and independently. The measured results depicted that the antenna is able to covers the bandwidth from 2.6 to 10.4 GHz for VSWR≤ 2 excluding the rejected bands from 3.1 to 3.8 GHz and 5.0 to 6.0 GHz. Acceptable VSWR and radiation pattern characteristics are earned on the frequency band of interest.

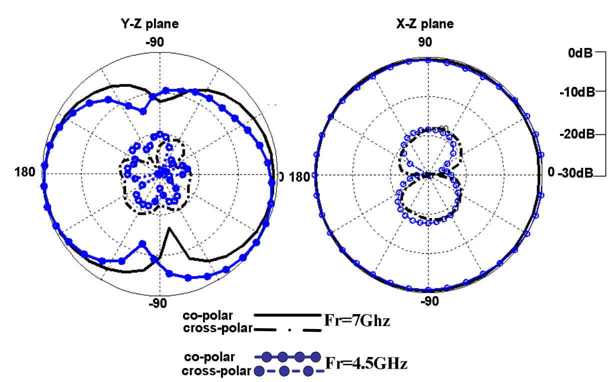

Fig. 10. Measured radiation patterns of the proposed antenna at 4.5 and 7GHz.

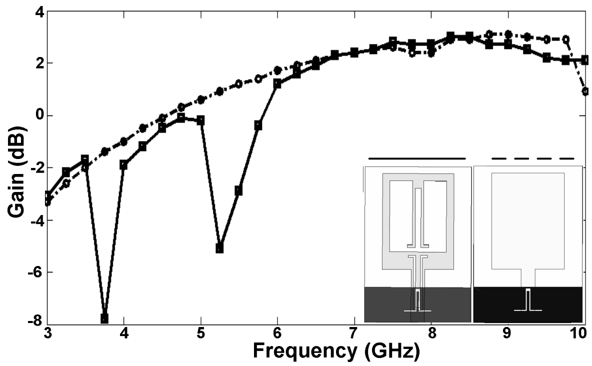

Fig. 11. Maximum gain comparisons for the ordinary square antenna (without notched band), and the proposed antenna (with notched band)

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