A Novel Antenna With Dual Band-Notched Characteristics using Shorting Pin and Z-Shaped Slot on Conductor Backed

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Abstract **─** In this paper, a novel UWB antenna with dual notched bands is presented. The antenna consists of a square patch and a ground plane with a Ω-shaped slot, which increase the bandwidth from 2.7 GHz to 11.3 GHz. To achieve two bands stop, both Z-shaped slot on conductor backed plane and strip ended up a shorting pin are used. The designed antenna has a small size of 15 × 22 mm^2 while indicating the band-stop performance in the frequency bands of 3.1 GHz to 3.8 GHz and 5.1 GHz to 6.1 GHz in order.

Index Terms **─** Antennas, DGS (defected ground structure), notch band, and UWB (ultra wide band).

I. INTRODUCTION

In UWB communication systems, the design of a compact planar antenna whilst providing wideband characteristic over the whole operating band is one of main subjects. Consequently, plenty of microstrip antennas with various configurations have been experimentally characterized. Meanwhile, various strategies to rise the impedance bandwidth have been investigated [1-4]. However, The frequency range for UWB systems between 3.1 GHz and 10.6 GHz will cause interference to the existing wireless communication systems, namely, the wireless local area network (WLAN) for IEEE 802.11a operating at 5.15 GHz – 5.35 GHz and 5.725 GHz – 5.825 GHz, the IEEE 802.16 WiMAX system 3.3 GHz – 3.69 GHz, 5.25 GHz – 5.85 GHz, therefore, UWB antenna with a dual band stop performance is needful. To achieve the frequency band-notch function antenna, modified planar monopole antennas have been recently presented [5-8]. In this manuscript, a novel dual band-notch antenna is proposed. Related to it, to increase impedance bandwidth is used with an Ω-shaped slot in the ground plane. Also, based on electromagnetic coupling theory (ECT), single band-notched function is provided by inserting a Z-shaped slot on conductor backed plane. In addition, dual band-notch characteristic is obtained by using a strip ended up shorting pin. Good VSWR and radiation pattern characteristics are obtained in the frequency band of interest. Simulated and measured results are presented to validate the usefulness of the antenna structure for UWB applications.

II. ANTENNA DESIGN

Figure 1 exhibits the geometry of the proposed antenna. The antenna is fabricated on FR4 substrate with ε_r = 4.4, h = 1 mm, fed by a microstrip line and has a size of 15 × 22 mm^2. The microstrip feed line is designed for a 50 Ω characteristic impedance with fixed 1.9 mm feed line width and 7.5 mm length. It means that the antenna is connected to a 50 Ω SMA connector for signal transmission. The antenna contains a square patch with Wp = 10 mm and Lp = 13.5 mm, and a partial ground plane with length Lg = 5 mm. By cutting a novel Ω-shaped slot into the ground

Submitted On: Feb. 19, 2013
Accepted On: June 14, 2013

plane, as illustrated in Fig. 1, and carefully adjusting its parameters, impedance bandwidth enhancement may be achieved because they can adjust the electromagnetic coupling effects between the patch and the ground plane, and it can improve the impedance bandwidth without any cost of size or expense. Meanwhile, to obtain two notched bands has been used two different techniques, the former DGS (defected ground structure), and the latter shorting pin that will more be examined. Regarding to DGS, by inserting a Z-shaped slot in the conductor backed plane, a notched band at centre frequency 5.5 GHz can be earned while by using a strip line, with length W8 + L8, ended up shorting pin, another band stop at centre frequency 3.5 GHz is obtained.

III. ANTENNA PERFORMANCE AND DISCUSSION

In this section, the square monopole antenna with different design parameters are 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 achieved using the Ansoft simulation software high-frequency structure simulator [9]. Table I gives optimal dimensions of the designed antenna. Figure 2 shows the structure of two different square antennas. As illustrated in Fig. 3, VSWR (voltage standing wave ratio) characteristics for both antennas shown in Fig. 2 is compared to each other. It is quite apparent that by inserting an Ω-shaped slot in the ground plane, it can adjust the electromagnetic coupling effects between the patch and the ground plane, which result in creating the third resonance at nearly 11 GHz and increasing the impedance bandwidth.

Figure 4 illustrates three antenna structures indicating major elements of creator filtering properties in the WiMAX/WLAN bands stop-bands including the Z-shaped slot in the conductor backed plane and the strip line ended up a shorting pin. Figure 5 shows the VSWR characteristics for the three mentioned antennas shown in Fig. 4. From the results, it is found that the Z-shaped slot in the conductor backed plane have main effect on the notched band at center frequency 5.5 GHz. Whereas the strip line ended up a shorting pin creates a stop band at center frequency 3.5 GHz to filter WLAN and WiMAX bands in order. Meanwhile, it is found out that both notches are autonomous than each other. It means that they have no effect on each other. It is interesting to note that by adjusting the length of the set of parameters, the centre frequencies of the notched bands can be controlled. Figure 6 illustrates the VSWR of the antenna for different values of W7. As shown in Fig. 6, parameter W7 has a considerable influence on frequency shifting in a way that by varying W7, the centre frequencies of the notched bands can be finely tuned. By selecting the optimum parameter W7 = 9.1 mm, the frequency notched-band centered at 5.5 GHz can be achieved.

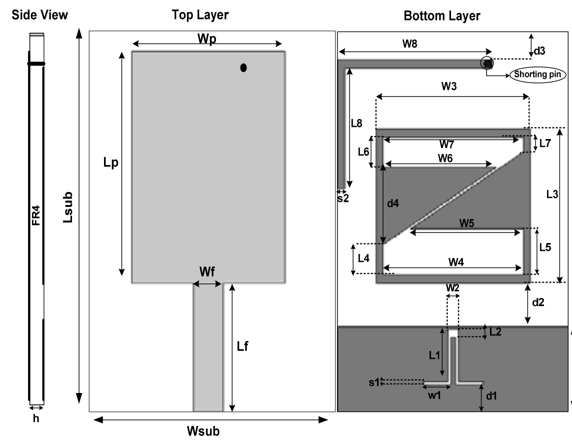

Fig. 1. Geometry of the proposed antenna.

Table I: Optimal parameter values of the antenna.

Wsub	Lsub	Wp	Lp	Wf	Lf	Lg	W1
15	22	10	13.5	1.9	7.5	5	1.8
L1	W2	L2	W3	L3	W4	L4	W5
3	0.7	0.4	10	9	9.1	1.75	7.35
L5	W6	L6	W7	L7	W8	L8	d1
2.65	7.35	1.75	9.1	0.85	10	7	1.6
d2	d3	d4	S1	S2	h	ε_r	δ
2.5	0.5	4.5	0.2	0.5	1	4.4	0.02

As mentioned before, in this study, to obtain the band-stop performance on WiMAX band with center frequency 3.5 GHz, a strip line is used with length W8+L8 that has been connected to a shorting pin. The simulated VSWR curves with different values of L8 are plotted in Fig. 7. As shown in Fig. 7, when L8 increases, the center frequency of the notched band is fallen and vice versa. Therefore, the optimized L8 is 7 mm. From these results, we can conclude that the notch frequencies are controllable by changing values W7 and L8.

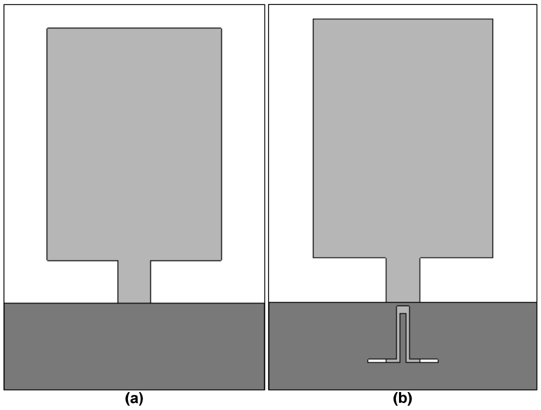

Fig. 2. (a) The simple square antenna and (b) the antenna with an Ω-shaped slot in the ground plane.

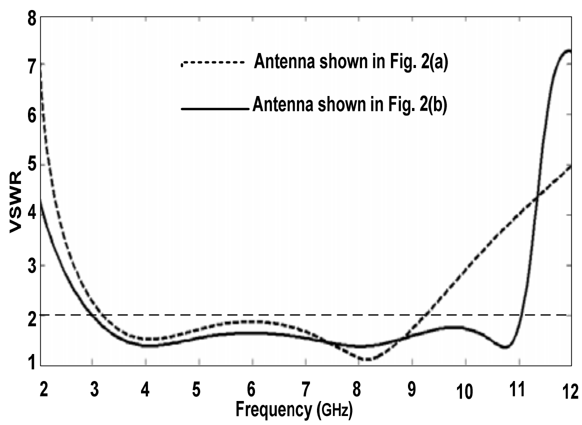

Fig. 3. Simulated VSWR characteristics for the diverse square antennas shown in Fig. 2.

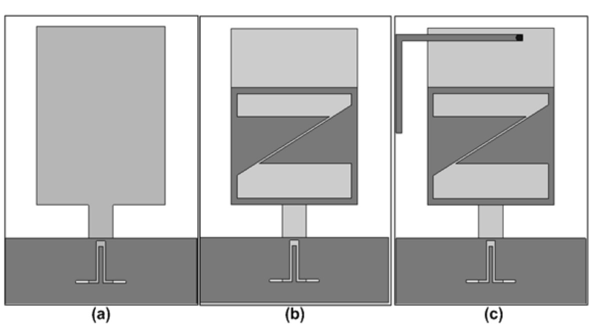

Fig. 4. (a) The simple square antenna, (b) the square antenna with a Z-shaped slot in the conductor backed plane, and (c) the proposed antenna.

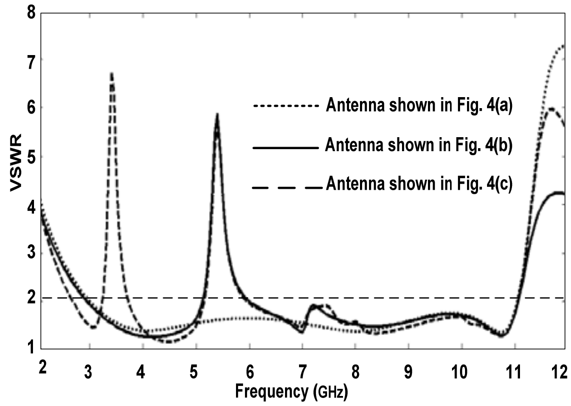

Fig. 5. Simulated VSWR characteristics for the antennas shown in Fig. 4.

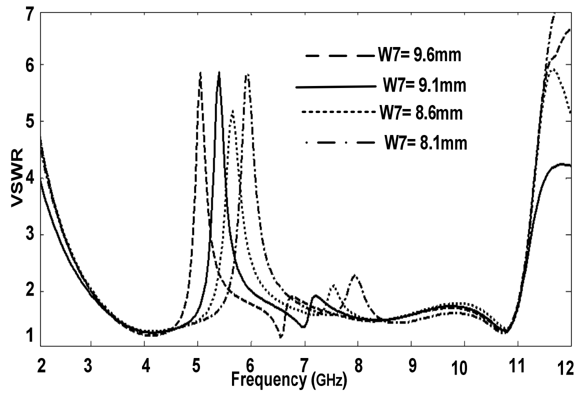

Fig. 6. Simulated VSWR characteristics of the antenna with a Z-shaped slot in the conductor backed plane with different values of W7.

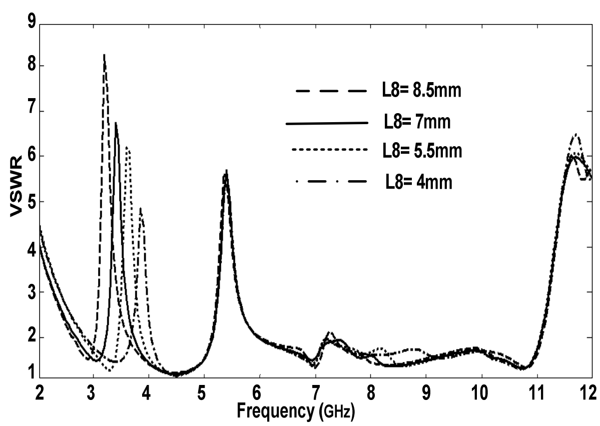

Fig. 7. Simulated VSWR characteristics of the antenna with a strip line ended up shorting pin with different values of L8.

To be clear more, Fig. 8 is used indicating the simulated current distributions on the antenna. It can be observed that at 5.5 GHz the greatest current is concentrated in the conductor backed plane with Z-shaped slot while at 3.5 GHz the most current distribution is seen on the strip line.

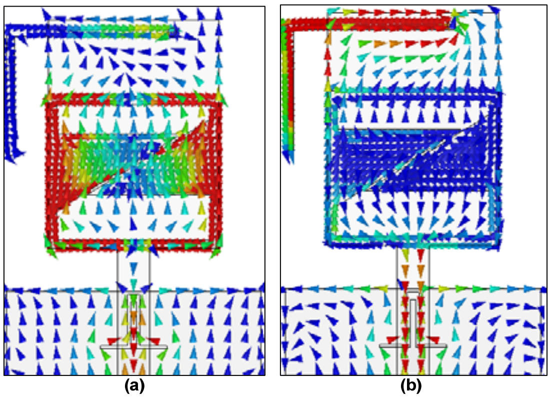

Fig. 8. Simulated surface current distributions (a) on the conductor backed plane at 5.5 GHz and (b) on the strip line at 3.5 GHz.

The photo of the fabricated antenna with optimal design is exhibited in Fig. 9. Besides, the antenna was tested in the antenna measurement laboratory at Iran Telecommunication Research Center. The measured VSWR of the proposed antenna, using an Agilent 8722ES vector network analyzer, is also shown in Fig. 10. It can be seen that the designed antenna has a wideband performance from 2.7 GHz to 11.3 GHz for VSWR ≤ 2, with dual notched bands of 3.1 GHz – 3.8 GHz and 5.1 GHz – 6.1 GHz. As shown in Fig. 10, there is a discrepancy between measured data and simulated results, and this could be due to the effect of the SMA port. 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 11 depicts the measured gain of the proposed antenna with and without notched bands. A sharp drop of gain is displayed in the notched frequencies band at 3.5 GHz and 5.5 GHz. For other frequencies outside the notched frequency band, the antenna gain with the slot is similar to those without it. Figure 12 exhibits simulated radiation efficiency of the proposed antenna. Radiation efficiency for over band is more than 90 % except two stop bands, which these results are exactly reasonable. On the other hand, Fig. 13 shows the measured normalized far-field radiation patterns in both H-plane (x–z plane) and E-plane (y–z plane) at frequencies 6.5 GHz and 8.5 GHz. It can be observed that the radiation patterns in the x–z plane are approximately omni-directional for the two frequencies whilst radiation pattern in the y-z plane are nearly a dipole-like.

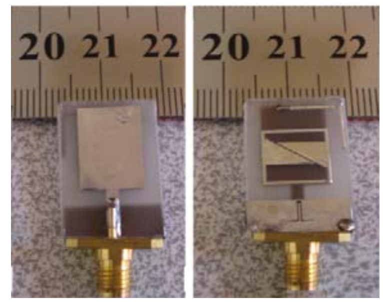

Fig. 9. Photograph of the fabricated antenna.

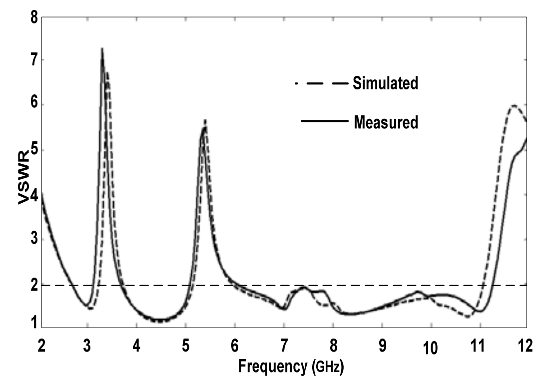

Fig. 10. Measured and simulated VSWR characteristics for the proposed antenna.

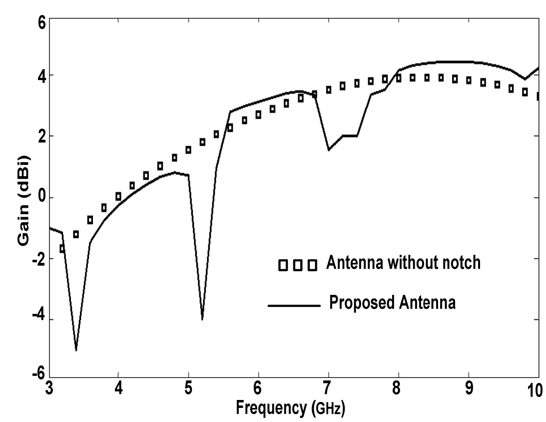

Fig. 11. Measured antenna gain of the proposed antenna without and with stop bands.

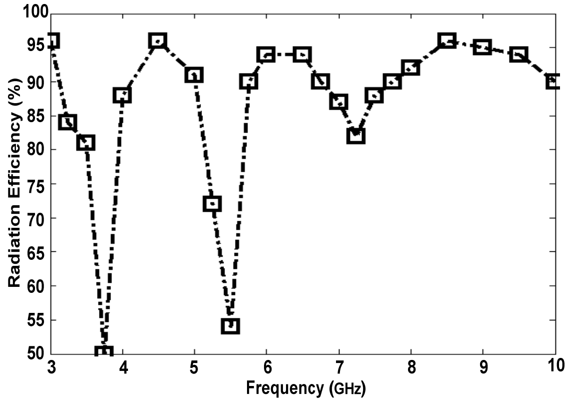

Fig. 12. Simulated radiation efficiency of the proposed antenna.

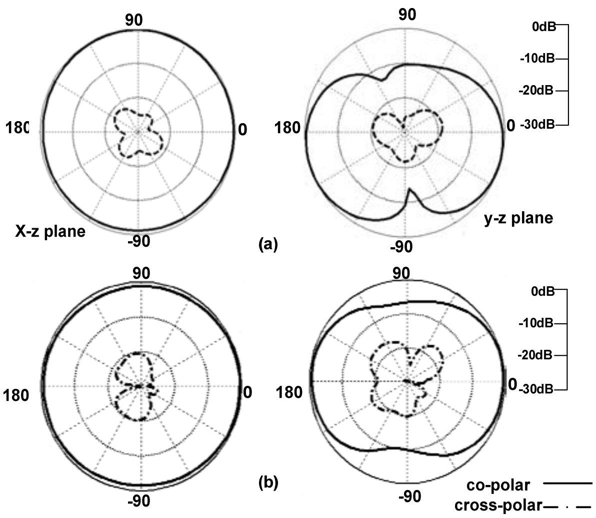

Fig. 13. Measured radiation patterns of the proposed antenna at (a) 6.5 GHz and (b) 8.5 GHz.

IV. CONCLUSION

A novel compact UWB antenna with dual band-notched characteristics has been proposed and discussed. In this design, by using an Ω-shaped slot, a wide impedance bandwidth from 2.7 GHz to 11.3 GHz with VSWR ≤ 2 is achieved. Furthermore, by applying a conductor backed plane with Z-shaped slot on it and a strip line ended up shorting pin, two frequency notched bands of 3.1 GHz – 3.8 GHz and 5.1 GHz – 6.1 GHz are obtained. The designed antenna has a small size of 15 × 22 mm^2. The good impedance matching characteristic, constant gain, and omni-directional radiation patterns makes this antenna a good candidate to be used in UWB applications and systems.

REFERENCES

[1] M. Mighani, M. Akbari, and N. Felegari, "Design of a small rhombic monopole antenna with parasitic rectangle into slot of the feed line for SWB application," *The Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 1, pp. 74-79, 2012.

[2] M. Akbari, M. Koohestani, Ch. Ghobadi, and J. Nourinia, "Compact CPW-fed printed monopole antenna with super wideband performance," *Microwave Opt. Techn. Lett.*, vol. 53, pp. 1481-1483, 2011.

[3] M. Akbari, M. Koohestani, Ch. Ghobadi, and J. Nourinia, "A new compact planar UWB monopole antenna," *International Journal of RF and Microwave Computer-Aided Engineering*, vol. 21, pp. 216-220, 2011.

[4] M. Mighani, M. Akbari, and N. Felegari, "A CPW dual band notched UWB antenna," *The Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 4, pp. 352-359, 2012.

[5] M. Abdollahi, H. Oskouei, M. Akbari, and M. Mighani, "A novel compact UWB antenna with triple band-notches for WiMAX/ WLAN/ ITU bands," *The Applied Computational Electromagnetics Society (ACES) Journal*, vol. 27, no. 12, pp. 1014-1021, 2012.

[6] A. A. Eldek, "Numerical analysis of a small ultra wideband microstrip-fed tap monopole antenna," *Prog. Electromag. Research (PIER)*, vol. 65, pp. 59-69, 2006.

[7] M. Ojaroudi, Gh. Ghanbari, N. Ojaroudi, and Ch. Ghobadi, "Small square monopole antenna for UWB applications with variable frequency band-notch function," *IEEE Antennas Wirel. Propag. Lett.*, vol. 8, pp. 1061-1064, 2009.

[8] R. Rouhi, Ch. Ghobadi, J. Nourinia, and M. Ojaroudi, "Ultra-wideband small square monopole antenna with band notched function," *Microwave Opt. Technol. Lett.*, vol. 52, pp. 2065-2069, 2010.

[9] Ansoft High Frequency Structure Simulation (HFSS), Ver. 10, Ansoft Corporation, Pittsburgh, PA, 2005.

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