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A New Notched Microstrip-fed Hexagonal Monopole Antenna for UWB Operation

Sabour SOLHKHAH Changiz GHOBADI Javad NOURINIA Davood AHMADIAN
Electrical Engineering Department, Urmia University, 165, Urmia 57153, IRAN

Corresponding author
E-mail: davod.ahmadian@gmail.com

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Abstract

In this paper, we present a novel microstrip fed hexagonal monopole antenna with a new filter function, for UWB applications. The antenna is fabricated on a 1mm-FR4 substrate and measured results have good agreement with simulated results. By tuning the angles of the hexagonal radiating patch and inserting two slots in the ground plane, a great impedance bandwidth with a very good impedance matching can be achieved. Two L-shaped slits are inserted in the radiating patch and provide the band-notch characteristic. The designed antenna has a small size of 18 mm × 20 mm and operates over the frequency band between 3 to 16 GHz for VSWR < 1.4, rejecting the undesired frequency band from 5.1 to 5.85 GHz.

Keywords: Band rejection filter, microstrip-fed antenna, ultra-wideband monopole.

INTRODUCTION

The development of ultra-wideband (UWB) applications as a part of wireless technology has increased the demand for ultra wideband antennas. The commercial usage of UWB frequency band in wireless systems, from 3.1 to 10.6 GHz, was approved by Federal communication commission (FCC) in 2002 [1]. Printed monopole antennas have received much attention due to their wideband matching characteristic, omnidirectional radiation patterns, high radiation efficiency, and simple hardware configuration. Hence, they are recently used in communication applications such as RFID devices, sensor networks, radar and location tracing [2-4]. On the other hand, the frequency range for UWB systems will cause interference to the existing wireless local area network (WLAN) operating from 5.15 to 5.85 GHz band. So the UWB antenna with a band-notched characteristic is required. It was demonstrated in [5-7] that by etching a specific feature in a planar monopole, a narrow and deep notch band can be achieved within a wide operating band.

In this paper a novel printed hexagonal monopole antenna with a new filter function in very compact size is proposed for UWB applications. The angles of the hexagonal radiating patch control the impedance matching and impedance bandwidth of the antenna. Two slots are inserted in the ground plane and cause to extend the upper frequency band. Two L-shaped slits are inserted in the radiating patch and provide the band-notch characteristic. The parametric of the proposed antenna is done using the Ansoft high frequency structure simulator (HFSS) [8]. Moreover, the proposed antenna is fabricated and the measured and simulated results are comprised.

MATERIALS and METHODS

The geometry of the proposed antenna is shown in Fig. 1. The proposed antenna which has a very small size of 18 × 20 mm^2 is printed on a conventional 1mm-FR4 substrate with relative permittivity of 4.4. The antenna structure is composed of a hexagonal radiating patch with two slits, 50-Ω microstrip-fed line and truncated ground plane of length L_g = 5.7 mm. The ground plane is on the opposite side of the substrate which two slots are inserted in. To achieve 50-Ω impedance match, the width of the microstrip feed line is fixed at 1.8 mm. The gap between the hexagonal patch and the ground plane is g = 1.7 mm. Detail parameters of the printed monopole antenna are shown in Fig. 1.

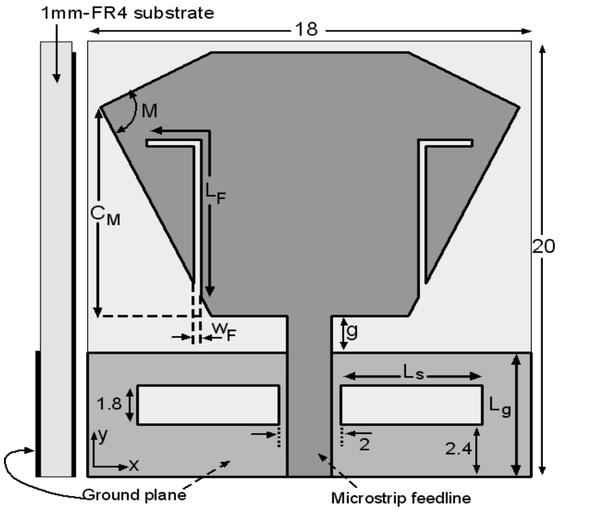

Figure 1. Geometry of the proposed monopole antenna (unit: mm).

RESULTS and DISCUSSION

To verify the performance of the proposed antenna, a parametric study is done. As depicted in Fig. 1, angle *M* is related to the two symmetric angles of the hexagonal patch. Effects of the value and position of the angle *M*, on the VSWR performance, are studied and shown in Fig. 2 and 3. It is observed from Fig. 2, as the angle *M* increases from 83 to 91 deg, the impedance matching of the second resonant mode improves and so the fractional impedance bandwidth greatly increases from 67 to 110%. Moreover, as the angle *M* increases to 108 deg the second resonant frequency and so the impedance bandwidth reduces. The simulated VSWR curves with the optimal angle *M* (= 95 deg) for various positions of, C_M, are plotted in Fig. 3. It can be seen that, as C_M increases from 8.5 to 17.5 mm, the fractional impedance bandwidth various from 75 to 100%.

As illustrated in Fig. 1, two narrow slits are inserted in the radiating patch, symmetrically. At the notch frequency, the surface current is concentrated around the edges of the slits and flows back to the feeding part at the notch frequency. This causes the antenna to operate in a transmission-line like mode which transforms the high impedance at the top side of the slots to nearly zero at the antenna feed point [9]. This is in turn, leads slits to act as a resonant structure. The resonant frequency varies by the changing of the total length of the slits, L_F. Also the bandwidth of the notched band depends on the width of the slits. Fig. 4 and Fig. 5 show that two L-shaped slits play a role in filter performance. In Fig. 4, it is observed that as the length L_F increases from 8 to 11.5 mm, the center frequency of notched band decreases from 6.5 to 4.3 GHz. The optimized value of L_F is 9.5 mm which approximately is 0.2λ, where λ corresponds to the band notch frequency (=5.5 GHz). The notched band widening effect of the width of the slits, W_F, is depicted in Fig. 5.

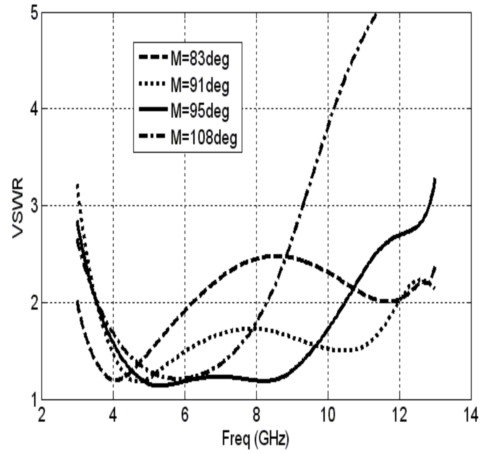

Figure 2. Simulated VSWR for various angle M (CM = 17 mm).

For the fixed length of the slits (=9.5 mm), the bandwidth of the rejected band increases from 6 to 35% as the width of the slits increases from 0.2 to 0.95 mm.

Creating slots in the ground plane has been regarded as a defected ground structure (DGS). The DGS applied to the microstrip line of the monopole antenna causes a new resonant frequency that is controllable by changing the length and width of the slots. Therefore by inserting two slots at the ground plane and tuning its parameters, much greater bandwidth can be achieved [5]. Fig. 6 shows that as the length of the slot, L_S, increases from 2 to 6.5 mm, the fractional impedance bandwidth of the antenna increases from 115 to 150%. The optimal values of the antenna parameters are mentioned in Table I. Antenna with the optimal values and using the slots in the ground plane has a great impedance bandwidth from 3 to 16 GHz.

Table I. Optimized parameters of the proposed antenna.

Lg	G	L_F	W_F	L_S	C_M	M
5.7 mm	1.7 mm	9.5 mm	0.65 mm	6.5 mm	17 mm	95 deg

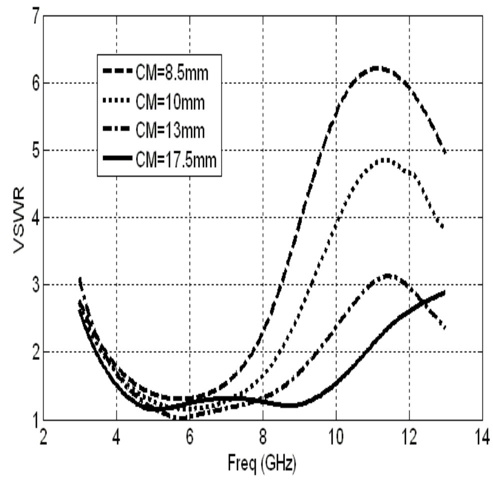

Figure 3. Simulated VSWR for various values of position, CM (M = 95 deg).

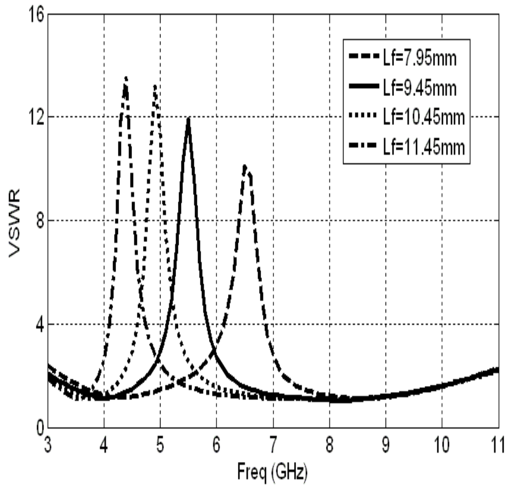

Figure 4. Simulated VSWR for various slit length, LF (WF = 0.3 mm).

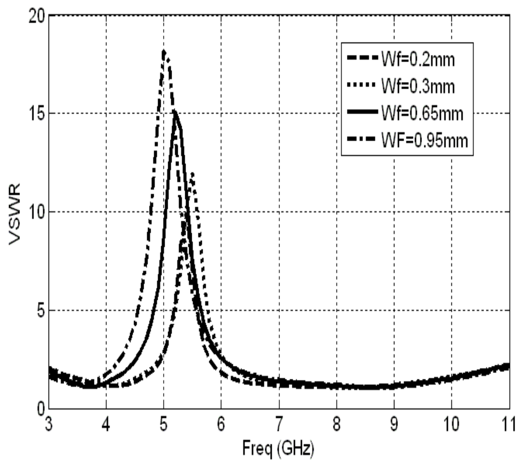

Figure 5. Simulated VSWR for various slit width, WF (LF = 9.45 mm).

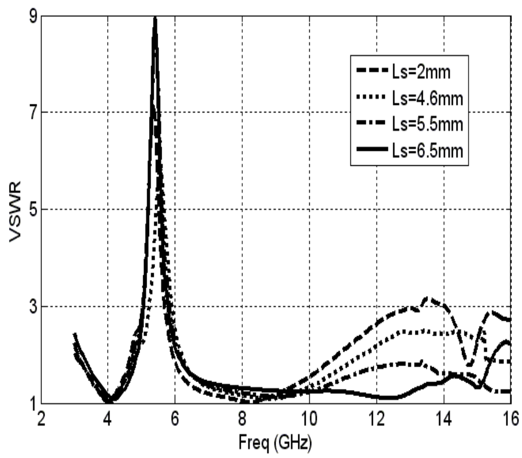

Figure 6. Simulated VSWR for various slot length, LS (M = 95 deg, CM = 17 mm, LF = 9.45 mm, WF = 0.3 mm).

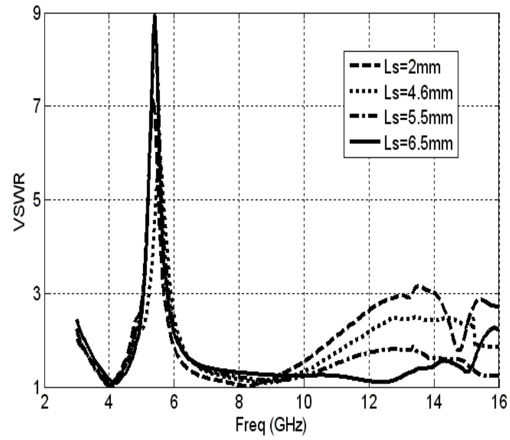

Figure 6. Simulated VSWR for various slot length, LS (M = 95 deg, CM = 17 mm, LF = 9.45 mm, WF = 0.3 mm).

Considering that the antenna VSWR curve is totally less than 1.4, which is important parameter in applied usage. Moreover, the band-rejection performance is insensitive to the changes of the L_S. Fig. 7 presents the photograph of the realized proposed monopole antenna with SMA connector. In Fig. 8 the measured result with band notch characteristic is compared with the simulation results with and without band notch function. A good agreement is seen between them with a little increase in the lower-edge frequency in the measured result. Fig. 9 shows the current distribution at the notch frequency of 5.5 GHz. In this figure, we can see more and stronger current density in the edges of the L-shaped slits than any other area at the notch frequency.

Typical radiation characteristics of the UWB antenna are also experimentally examined. Fig. 10 and Fig. 11 plot the measured normalized far-field radiation patterns at resonant frequencies of 4.1, 7, 9.8 GHz on the H-plane and E-plane. The antenna exhibits stable radiation properties as those of the conventional simple monopole

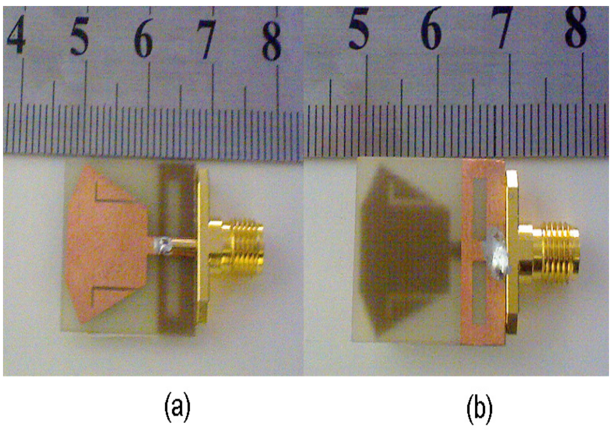

Figure 7. Photograph of the realized proposed antenna, (a) front view and (b) back view.

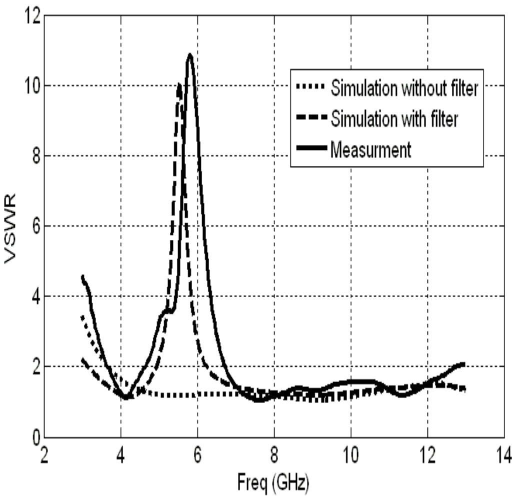

Figure 8. Comparison between the simulated and measured results.

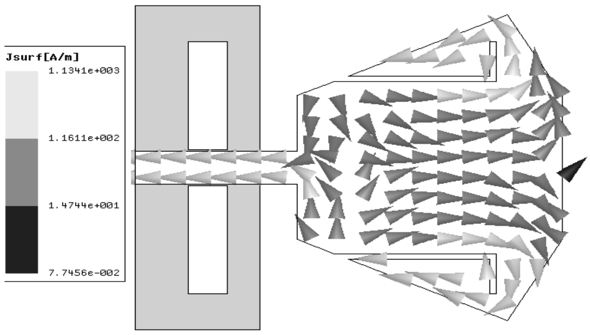

Figure 9. Simulated current distributions at: 5.5 GHz (notch frequency).

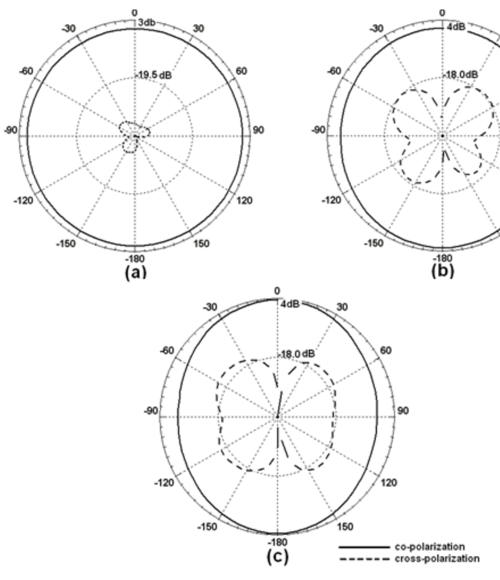

Figure 10. Measured H-plane radiation pattern for the proposed antenna at: (a) 4.1 GHz, (b) 7 GHz and (c) 9.8 GHz.

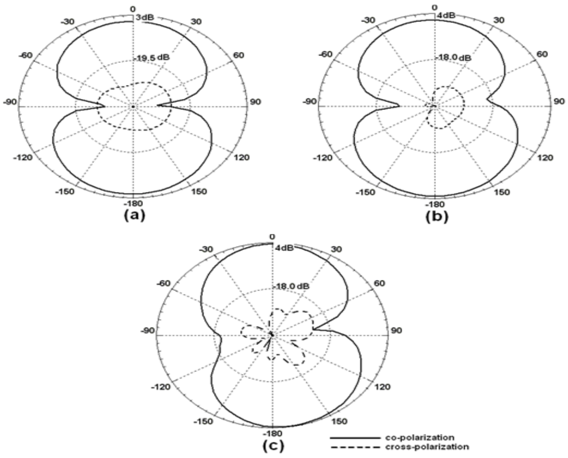

Figure 11. Measured E-plane radiation pattern for the proposed antenna at: (a) 4.1 GHz, (b) 7 GHz and (c) 9.8 GHz.

antennas. The patterns in the H-plane are omnidirectional in all UWB frequencies and they are in symmetry with respect to the antenna axis (θ = 0 deg), since the proposed antenna's structure is symmetrical. In the E-plane, the radiation patterns remain roughly a dumbbell shape over the frequency band. The cross-polarization levels are generally much lower than the co-polarization ones. Finally, the experimental peak gains of the proposed antenna across UWB band are shown in Fig. 12, with and without the filter structure. A sharp decrease of antenna gain is observed in the notch frequency. For other in-band frequencies, the antenna gain is nearly flat and is similar to those without filter structure.

CONCLUSION

A small band-notched printed monopole antenna has been proposed for UWB applications. It is demonstrated that by tuning the angles of the hexagonal radiating patch and inserting two slots in the ground plane, a great impedance bandwidth with a very good impedance matching can be achieved. The presented antenna exhibits a broad impedance bandwidth and good impedance matching from 3 to 16 GHz. To realize a sharp rejection frequency band from 5.1 to 5.85 GHz, Two L-shaped

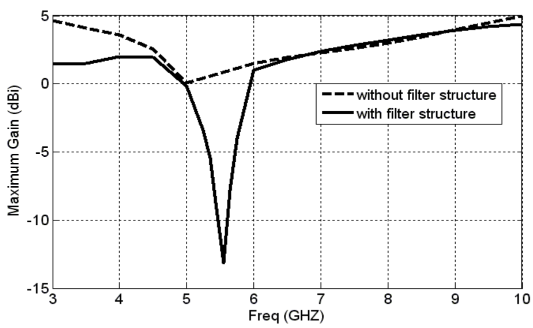

Figure 12. Maximum measured Gain of the proposed antenna with and without filter structure.

slits are inserted in the radiating patch and provide the band-notch characteristic. Good radiation patterns and acceptable maximum gain are obtained over whole frequency band.

ACKNOWLEDGMENT

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