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A NOVEL UWB ELLIPTICAL SLOT ANTENNA WITH BAND-NOTCHED CHARACTERISTICS

R. Fallahi

Iran Telecommunication Research Center (ITRC)
P.O. Box 14155-3961, Tehran, Iran

A.-A. Kalteh

Science & Research Branch of Islamic Azad University (SRBIAU)
Tehran, Iran

M. Golparvar Roozbahani

Iran Telecommunication Research Center (ITRC)
P.O. Box 14155-3961, Tehran, Iran

Abstract—This paper presents a novel band-notched elliptical slot antenna for Ultra Wide-Band (UWB) communication, which is printed on a dielectric substrate of RT/duroid 6006 with relative permittivity (ε_r) of 6.0, thickness of 1.27 mm, and fed by an elliptical open ended microstrip line connected to the 50 Ω main line. This antenna is designed to be used in frequency band of 3.1–10.6 GHz. Band-notched characteristics of antenna to reject the frequency band of 5.15–5.825 GHz, which is limited by IEEE 802.11a, is realized by parasitic inverted-U strip attached to the elliptical slot plane. Effects of varying the parameters of parasitic inverted-U strip on performance of proposed antenna have been investigated. The antenna with optimal parameters obtained from parametric study is fabricated and measured. It is observed that the simulation and experimental results have good agreements with each other.

1. INTRODUCTION

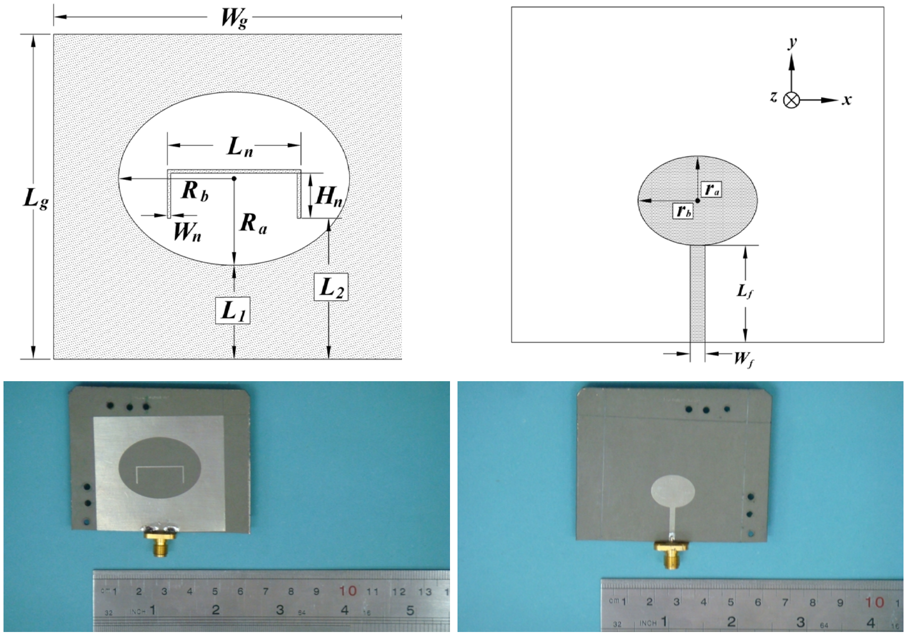
With the emergence and acceptance of the ultra wide-band (UWB) impulse radio technology in the USA [1], there has been considerable research effort put into UWB radio technology worldwide. Recently, the Federal Communication Commission (FCC)'s allocation of the frequency band 3.1–10.6 GHz for commercial use has sparked attention on ultra-wideband (UWB) antenna technology in the industry and academia. Several antenna configurations have been studied for UWB applications [2–7]. However, the frequency band of UWB communication systems includes the IEEE 802.11a frequency band; i.e., 5.15–5.825 GHz. Therefore, UWB communication systems may generate interference with wireless local-area networks (WLANs) based on IEEE 802.11a standard. To overcome problems caused by electromagnetic interference (EMI) between UWB and WLAN systems, various UWB antennas with a notch function have been developed for UWB communication systems [8–16].

The proposed antenna in this paper covers the commercial UWB frequency range (i.e., 3.1–10.6 GHz), while rejecting the limiting band (i.e., 5.15–5.825 GHz) to avoid possible interferences with existing communication systems running over it. The band rejection of the antenna is provided by attaching a parasitic inverted-U strip to the top layer of it. Effects of varying the parameters of this inverted-U strip on performance of antenna have also been studied. Performance simulations of the antenna were performed with IE3D software, which is based on the method of moments [17]. Designed antenna with optimal dimensions was fabricated and measured. An extensive comparison between experimental and simulation results is made, which demonstrates good agreement over approximately the entire operating frequency range.

The remaining of this paper organized as follows. Section 2 presents the configuration of the antenna. Parametric study of our proposed antenna is presented in Section 3. Simulation and measurement results accompanied with some discussions are presented in Section 4. Finally, Section 5 concludes the paper.

2. ANTENNA CONFIGURATION

The geometry and photograph of the proposed UWB band-notched elliptical slot antenna with its parameters are depicted in Figure 1. The antenna is located in x-y plane and the normal direction is parallel to z-axis. The proposed antenna is fabricated on a dielectric substrate of RT/duroid 6006 with relative permittivity (ε_r) of 6.0, thickness of



(a) Top Layer (b) Bottom Layer

Figure 1. Geometry and photograph of proposed UWB antenna; (a) Elliptical slot with parasitic strip, (b) Feed network.

1.27 mm, and ground plane size of $L_g \times W_g = 45\,\text{mm} \times 50\,\text{mm}$. For this antenna, the radiation element consists of an elliptical slot with axes of R_a and R_b (see Figure 1(a)), that is fed by an elliptical open ended microstrip line with axes of ra and rb (see Figure 1(b)). Elliptical open ended microstrip line is connected to the $50\,\Omega$ main line with $W_f = 2\,\text{mm}$ (see Figure 1(b)). The band-notched characteristics of antenna are achieved by attaching parasitic inverted-U strip to the slotted layer (top layer) of antenna. The band-notched characteristics can be controlled by proper adjusting of parasitic inverted-U strip parameters.

3. EFFECTS OF NOTCH PARAMETERS ON ANTENNA PERORMANCE

The bandwidth and center frequency of notched band are the most important parameters of a band-notched antenna. In this section, we study the effects of parasitic inverted-U strip parameters (i.e., L_n and

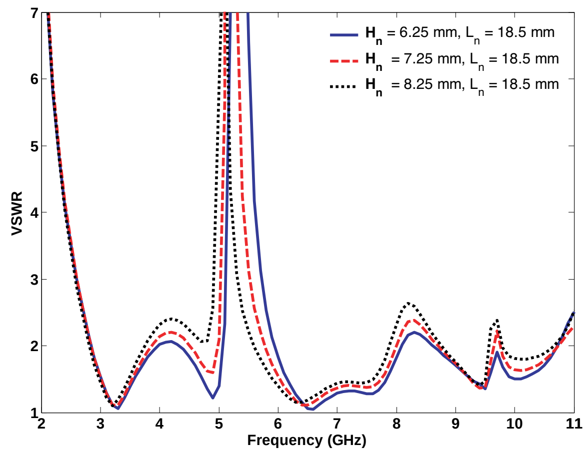


Figure 2. Effects of parameter H_n of the inverted-U strip on the band-notched characteristics of antenna.

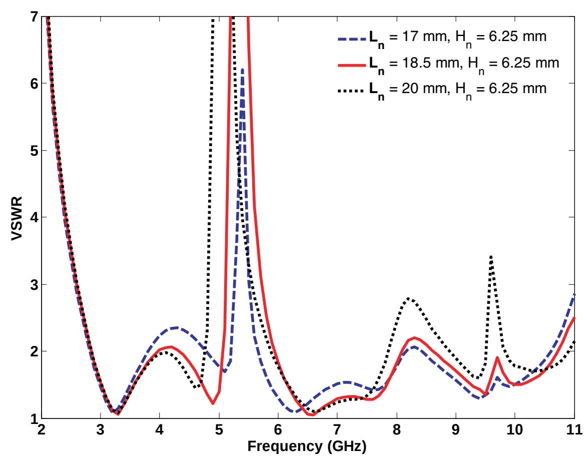


Figure 3. Effects of parameter L_n of the inverted-U strip on the band-notched characteristics of antenna.

H_n) on the band-notched characteristics of proposed antenna.

Figure 2 illustrates the simulated VSWR of the proposed antenna for $H_n = 6.25, 7.25$, and 8.25 mm with $L_n = 18.5$ mm. It is observed that the center frequency of notched band is shifted toward lower frequencies by increasing the length of H_n.

The VSWR curves of the antenna with different lengths of L_n are depicted in Figure 3. It is seen that for $L_n = 17, 18.5$, and 20 mm with

$H_n = 6.25$ mm, the center frequency of notched band is shifted toward lower frequencies and notched bandwidth is increased by increasing the length of L_n.

4. RESULTS AND DISCUSSIONS

Simulation and measurement results of VSWR, current distributions, radiation patterns, and gain of the proposed antenna are investigated in this section. The simulations are performed by using the IE3D software which utilizes the method of moments for electromagnetic computations. The VSWR of antenna is measured by the Agilent 8722ES Network Analyzer, whereas the radiation patterns and gain measurements are performed in anechoic chamber of Antenna Laboratory of Iran Telecommunication Research Center (ITRC).

The simulated and measured VSWR for designed band-notched elliptical slot antenna with dimensions indicated in Table 1 are illustrated in Figure 4. From this figure we can see that the calculated bandwidth of our proposed antenna is from 2.84 GHz to 10.75 GHz with a notched frequency band of 5.08–5.9 GHz. By measuring return loss of fabricated antenna, the frequency bandwidth of 2.55 GHz to upper 11 GHz with VSWR ≤ 2 and a 4.9–5.95 GHz notched bandwidth with VSWR ≥ 2 is achieved. Obviously, this measured frequency range covers commercial UWB band (3.1–10.6 GHz) and rejects the frequency band of IEEE 802.11a to overcome EMI problems between UWB and WLAN systems. As it is observed, there is a good agreement between expected numerical values and experimental results.

Table 1. Parameters of the proposed antenna (see Figure 1).

Parameter	L_g	W_g	R_a	R_b	L_f	W_f	L_1	L_2	r_a	r_b	H_n	L_n	W_n
Value (mm)	45	50	12	16	13	13	13	19	6	8	6.25	18.5	0.5

Figure 5 shows the simulated current distributions of our proposed antenna at frequencies 3.5, 5.15, 9.0, and 10.5 GHz for the optimal design. As shown in Figure 5(b), we can see that the current is mainly distributed on the parasitic inverted-U strip, which results in band-stop effect. In Figures 5(a), 5(c), and 5(d), weak current distribution on the parasitic inverted-U strip is observed. The natural interpretation is that the parasitic strip is not the major contributor of antenna

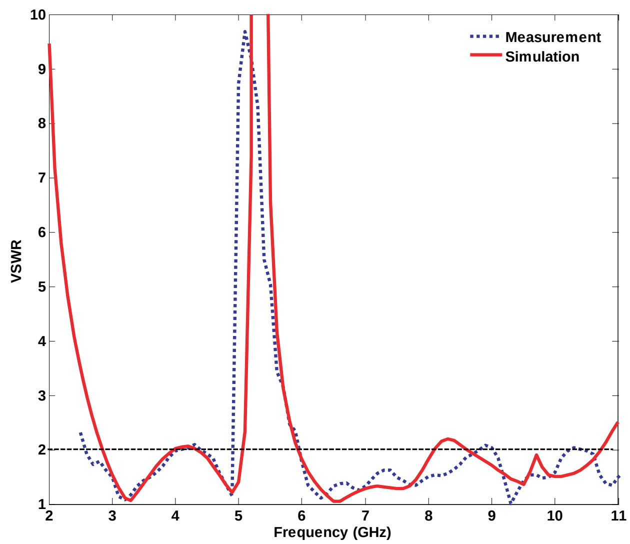


Figure 4. Simulated and measured VSWR of proposed antenna with dimensions of Table 1.

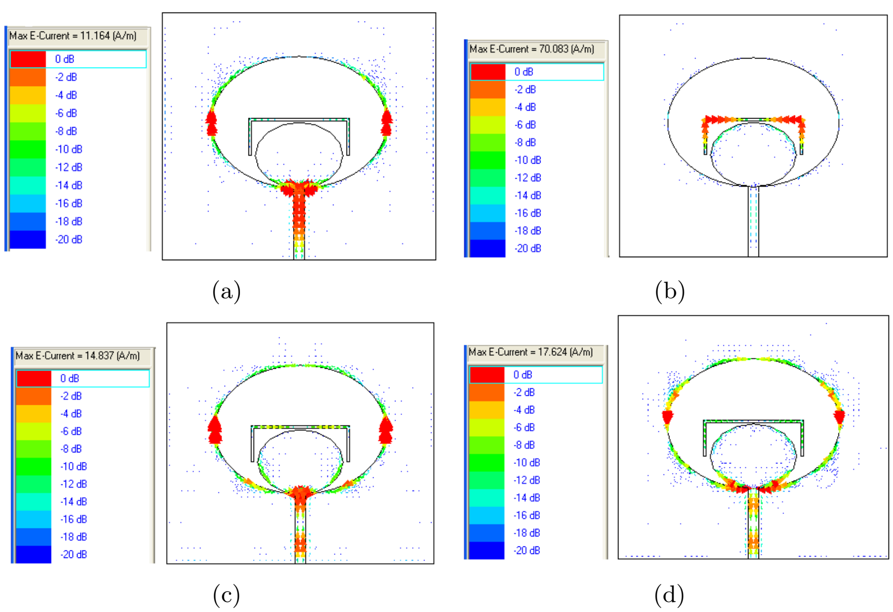


Figure 5. Simulated current distributions of proposed antenna at: (a) 3.5 GHz, (b) 5.15 GHz, (c) 9.0 GHz, and (d) 10.5 GHz.

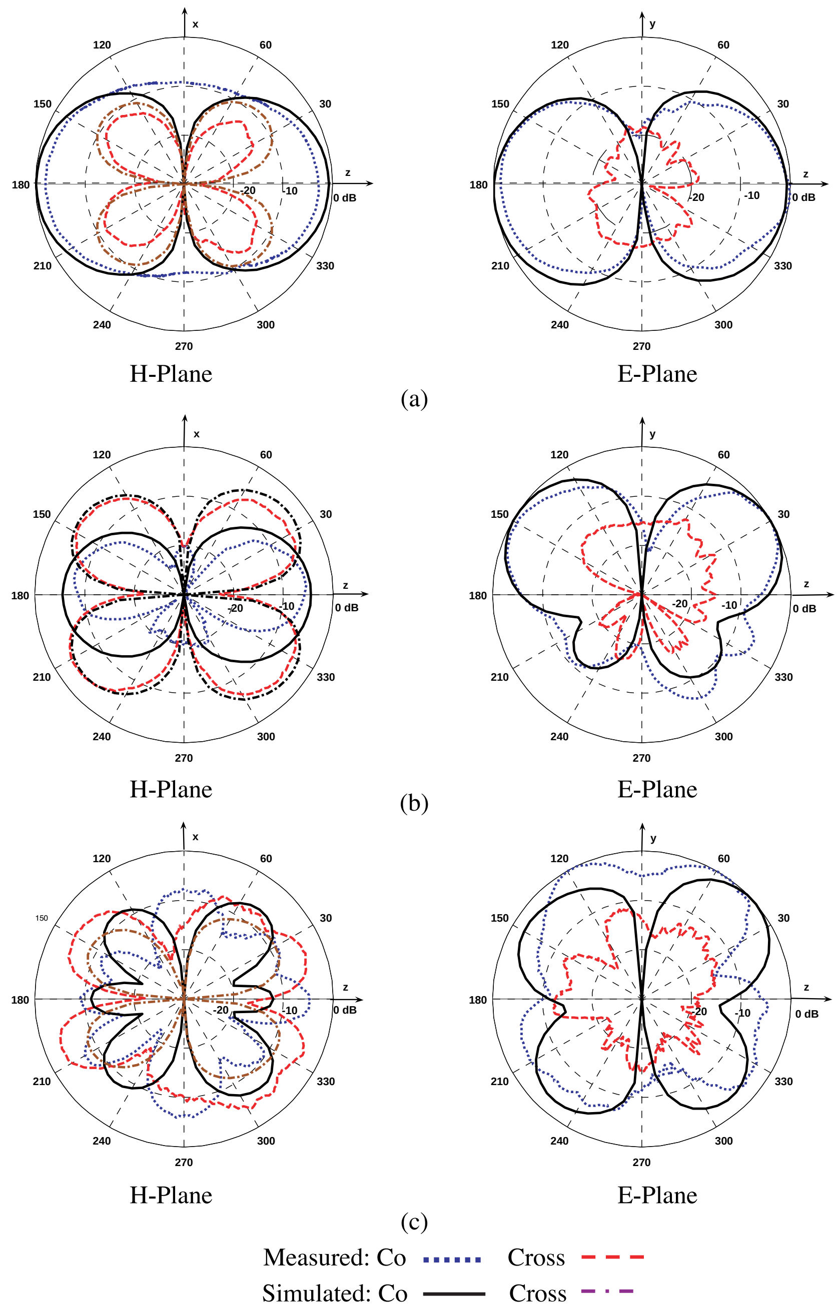


Figure 6. Simulated and measured radiation patterns of proposed antenna at frequencies (a) 4 GHz, (b) 7 GHz, (c) 10 GHz.

performance except for the notch frequency.

The simulation and measurement normalized radiation patterns of the proposed antenna in H-plane (or x-z) and E-plane (or y-z) at frequencies 4, 7, and 10 GHz are plotted in Figure 6. At lower frequencies, it is seen that our proposed design exhibits as an omni-directional profile for the x-z plane and a bi-directional one for the y-z plane. With the increase of frequency, the proposed antenna becomes more directive, but still remains bi-directional. By comparing measured and simulated patterns of Figure 6, a good agreement is observed.

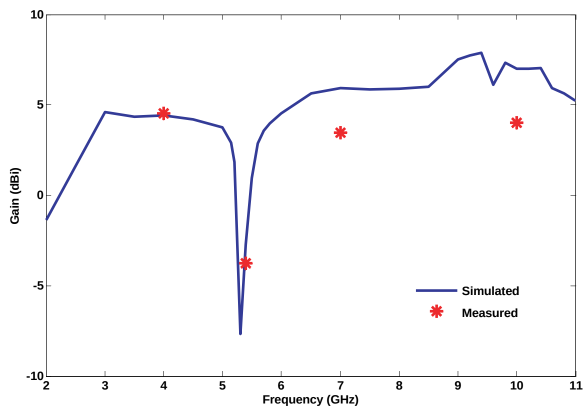


Figure 7. Simulated and measured gain of the proposed antenna.

The curve of simulated gain of our proposed antenna is illustrated in Figure 7. It reveals that the antenna gain ranges from 4.6 to 7.0 dBi within 2.84–10.75 GHz frequency band; of course, except for the notched band (5.08–5.9 GHz) where the gain decreases even to −7.7 dBi. The measured gain of the antenna at some frequencies is also depicted in Figure 7 by star symbols. The maximum gain obtained from measurements in desired frequency bandwidth is around 4.7 dBi, whereas in the notched bandwidth it shrinks to around −4.5 dBi.

5. CONCLUSION

A novel band-notched ultra wide-band elliptical slot antenna is proposed in this paper. In order to obtain band elimination characteristic, inverted-U strip is parasitically attached to the elliptical slot antenna. Band-notched characteristics can be controlled by adjusting inverted-U strip parameters. Parametric studies of antenna are presented. The proposed antenna design with optimal dimensions is fabricated and experimented. The measurements show that VSWR is below 2 within the desired frequency bandwidth from 2.55 GHz to upper 11 GHz, whereas a notched bandwidth of 4.9–5.95 GHz is obtained. Current distributions, far-field radiation patterns, and gain of the antenna are also studied in this paper. Good agreement has been found by comparing the results from the measured data and those simulated.

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REFERENCES

1. FCC report and order for part 15 acceptance of ultra wideband (UWB) systems from 3.1–10.6 GHz, Washington, DC, 2002.
2. Chair, R., A. A. Kishk, K. F. Lee, C. E. Smith, and D. Kajfez, "Microstrip line and CPW fed ultra wideband slot antennas with U-shaped tuning stub and reflector," *Progress In Electromagnetics Research*, PIER 56, 163–182, 2006.
3. Zhang, G.-M., J. S. Hong, B.-Z. Wang, Q. Y. Qin, J. B. Mo, and D.-M. Wan, "A novel multi-folded UWB antenna fed by CPW," *J. of Electromagn. Waves and Appl.*, Vol. 21, No. 14, 2109–2119, 2007.
4. Liang, J., C. C. Chiau, X. D. Chen, and C. G. Parini, "Study of a printed circular disc monopole antenna for UWB systems," *IEEE Transactions on Antennas and Propagation*, Vol. 53, No. 11, 3500–3504, November 2005.
5. Angelopoulos, S., A. Z. Anastopoulos, D. I. Kaklamani, A. A. Alexandridis, F. Lazarakis, and K. Dangakis, "Circular and elliptical CPW-fed slot and microstrip-fed antennas for ultra wideband applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 5, 294–297, 2006.
6. Ray, K. P. and Y. Rang, "Ultra wideband printed elliptical monopole antennas," *IEEE Transactions on Antennas and Propagation*, Vol. 55, No. 4, 1189–1192, April 2007.

7. Zhou, H. J., Q. Z. Liu, J. F. Li, and J. L. Guo, "A swallow-tailed wideband planar monopole antenna with semi-elliptical base," *J. of Electromagn. Waves and Appl.*, Vol. 21, No. 9, 1257–1264, 2007.
8. Zhou, H. J., Q. Z. Liu, Y. Z. Yin, and W. B. Wei, "Study of the band-notched function for swallow-tailed planar monopole antennas," *Progress In Electromagnetics Research*, PIER 77, 55–65, 2007.
9. Lui, W. J., C. H. Cheng, Y. Cheng, and H. Zhu, "Frequency notched ultra-wideband microstrip slot antenna with fractal tuning stub," *IEE Electron. Lett.*, Vol. 41, No. 6, 294–296, Mar. 2005.
10. Wong, K. L., Y. W. Chi, C. M. Su, and F. S. Chang, "Band-notched ultra wideband circular-disk monopole antenna with an arc-shaped slot," *Microwave Opt. Technol. Lett.*, Vol. 45, No. 3, 188–191, May 2005.
11. Su, S. W., K. L. Wong, and F. S. Chang, "Compact printed ultra-wideband slot antenna with a band-notched operation," *Microwave Opt. Technol. Lett.*, Vol. 45, No. 2, 128–130, Apr. 2005.
12. Ren, W., Z. G. Shi, and K. S. Chen, "Novel planar monopole UWB antenna with 5-GHz band-notched characteristic," *J. of Electromagn. Waves and Appl.*, Vol. 21, No. 12, 1645–1652, 2007.
13. Akhoondzadeh-Asl, L., M. Fardis, A. Abolghasemi, and G. Dadashzadeh, " Frequency and time domain characteristic of a novel notched frequency UWB antenna," *Progress In Electromagnetics Research*, PIER 80, 237–348, 2008.
14. Chung, K., J. Kim, and J. Choi, "Wideband microstrip-fed monopole antenna having frequency band-notch function," *IEEE Microwave and Wireless Components Letters*, Vol. 15, No. 11, 766–768, Nov. 2005.
15. Kim, K.-H. and S.-O. Park, "Analysis of the small band-rejected antenna with the parasitic strip for UWB," *IEEE Transactions on Antennas and Propagation*, Vol. 54, No. 6, June 2006.
16. Zhang, G.-M, J.-S. Hong, and B.-Z. Wang, "Two novel band-notched UWB slot antennas fed by microstrip line," *Progress In Electromagnetics Research*, PIER 78, 209–218, 2008.
17. IE3D, Zeland Software. IE3D User's Manual Release 9. Zeland Software Inc. Available online: http://www.zeland.com.