Progress In Electromagnetics Research Letters, Vol. 59, 51–56, 2016

Design of Dual Band-Notched CPW-Fed UWB Planar Monopole Antenna Using Microstrip Resonators

Hany A. Atallah[1, 2, *], Adel B. Abdel-Rahman[1, 2], Kuniaki Yoshitomi[3], and Ramesh K. Pokharel[3]

Abstract—In this letter, a new coplanar waveguide (CPW) fed ultra-wideband (UWB) planar monopole antenna with dual band-reject characteristics is proposed. Two resonators of different lengths are employed at the bottom layer to create two notches at the frequency of interest. The proposed fabricated antenna works from 2.8 to 11.34 GHz with two notched bands which cover the WLAN (5.725–5.825 GHz) and ITU (8.025–8.4 GHz) bands. The proposed antenna is fabricated and measured for verification purposes. Good agreement between the measurement and simulation is found.

1. INTRODUCTION

Nowadays, ultra-wideband (UWB) technology has gained significant attention in the field of wireless communication due to its advantages, such as high data rate, low cost, simple hardware configuration, good resistance for multipath, and small emission power for short range access and remote sensing applications. The frequency range of the UWB system is released by the Federal Communications Commission (FCC) to be from 3.1 to 10.6 GHz. However, there are some other existing narrowband services that may cause interference with the UWB band, such as wireless local area network (WLAN), worldwide interoperability for microwave access (WiMAX), and international telecommunication union (ITU). To solve this problem, it is desirable to design antennas with band-notched characteristics to minimize potential interference. The UWB antennas with the rejection of single band [1], multiband [2, 3], and even reconfigurable bands have been presented and investigated [4]. Some of the recently used approaches include using electromagnetic band-gap (EBG) structure [5], defected ground structure (DGS) [6], etching different slots on the patch or ground [7–9], and PIN diodes [10]. Compared to these techniques, using microstrip resonators have some merits, such as stable radiation pattern, high VSWR, and simplicity to create notches. Consequently, the antenna design for UWB systems uses these techniques to remove the interference between UWB and narrowband systems, e.g., WLAN (5.15–5.35 and 5.725–5.825 GHz), and ITU service (8.025–8.4 GHz), and to be coexistent with these conventional wireless systems.

In this letter, a simple novel dual band-notched CPW-fed UWB antenna is presented, fabricated, and discussed. The proposed approach is based on using rectangular and meander line microstrip resonators at the bottom layer with different lengths to create the desired two rejection bands. Measured and simulated results are presented, compared, and discussed. Good agreement is found between the measured and simulated data. In Section 2, the structure and theory of the proposed dual band-notched antenna are discussed. Section 3 is devoted to the comparison of the simulated and measured results. Finally, a conclusion summarizes the results.

Received 3 February 2016, Accepted 8 March 2016, Scheduled 15 March 2016

* Corresponding author: Hany Ahmed Atallah (hany.mohamed@ejust.edu.eg).
[1] Electronics and Communications Engineering Department, School of Electronics, Communications and Computer Engineering, Egypt-Japan University of Science and Technology (E-JUST), Alexandria 21934, Egypt. [2] Faculty of Engineering, South Valley University, Qena 83523, Egypt. [3] E-JUST Center, School of Information Science and Electrical Engineering, Kyushu University, Nishi-ku, Fukuoka 819-0395, Japan.

2. THE PROPOSED ANTENNA DESIGN

The configuration of the proposed dual band-notched UWB antenna is shown in Fig. 1. The proposed antenna is designed on a low loss RO3003 substrate with thickness $h = 0.762$ mm and relative permittivity $\varepsilon_r = 3$. The dimensions of the antenna are about 40 mm×40 mm×0.762 mm. The patch dimensions are $W = L = 18$ mm, $L_2 = 2$ mm, and $W_2 = 12$ mm. The width of the feed line W_1 is fixed at 3 mm and the gap width is $g = 0.2$ mm to achieve 50 Ω characteristic impedance. A rectangular microstrip resonator and a meander line resonator are inserted on the bottom layer and beneath the CPW feed of an UWB planar antenna. The length and the width of the rectangular resonator are $L_r = 23$ mm, and $W_r = 1.8$ mm, respectively. The dimensions of the meander line resonator are $L_m = 28$ mm, $W_{mt} = 2.2$ mm, and a width of $W_m = 0.8$ mm. The operating frequency of the two resonators can be controlled by changing their lengths [11]. Because of the fringing effects, the total length of the resonator L_t (L_{rt} or L_{mt}) electrically looks greater than the physical dimensions and extended by Δ on each side. The effective length of the microstrip resonator $L_{t,eff}$ determines the fundamental resonant frequency and the harmonics. The microstrip resonator will resonate at its fundamental frequency f_o when its length $L_t = \lambda_{go}$. The notch frequency can be approximately estimated using

$$f_{notch} = \frac{nc}{L_{t,eff}\sqrt{\varepsilon_{eff}}}, \quad L_{t,eff} = L_t + 2\Delta_r \tag{1}$$

where $n = 1, 2, 3, \ldots$, Δ_r denotes the extended incremental length, c the velocity of the light in free space, and ε_{eff} the effective permittivity.

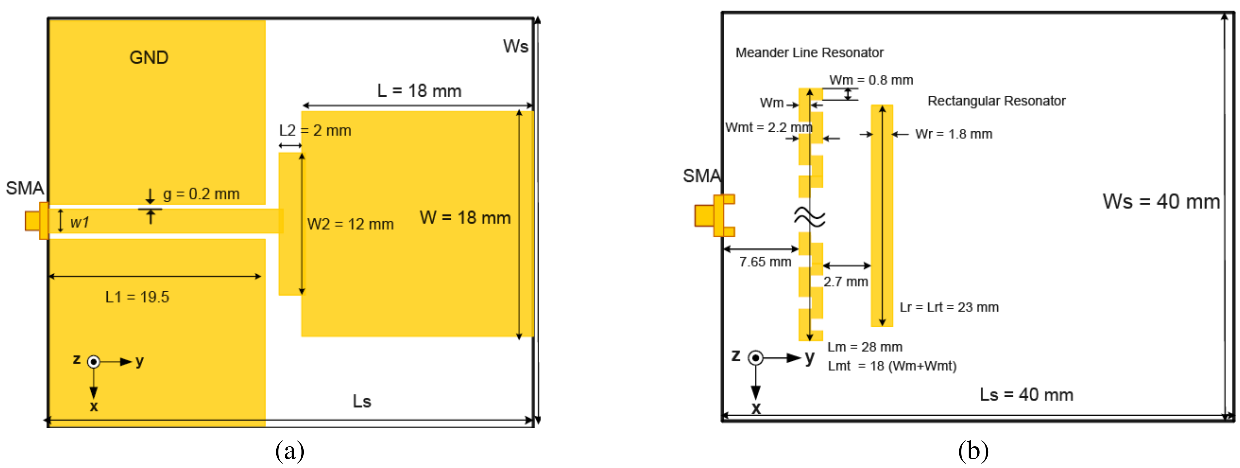

Figure 1. Structure of the proposed antenna: (a) Top view. (b) Bottom view.

The rectangular and meander line microstrip resonators are designed to produce notches at the WLAN (5.725–5.825 GHz) and ITU (8.025–8.4 GHz) bands using Equation (1). The electric field intensity distributions over the rectangular and meander line resonators at 8.2 and 5.78 GHz, respectively, were simulated and visualized using 3D full wave EM simulator CST [12]. These electric fields can clearly be observed in Fig. 2(a) and Fig. 2(b).

In both figures, the rectangular and meander line resonators have been indicated with white colors. It is obvious from these figures that the two resonators prevent successfully most of the fields from crossing to the radiator element, which act as a bandstop filter at the desired frequencies to generate dual band notches.

Figure 3 illustrates the simulated VSWR for different length values of the rectangular and the meander line resonator using the transient solver in the CST Microwave studio [12]. By varying the length of the rectangular resonator L_r from 20 to 32 mm, the center frequency of the notched band is easily tuned as shown in Fig. 3(a). The parametric study was done for the design with only the rectangular resonator then with only the meander line resonator. Fig. 3(b) shows the variation of the

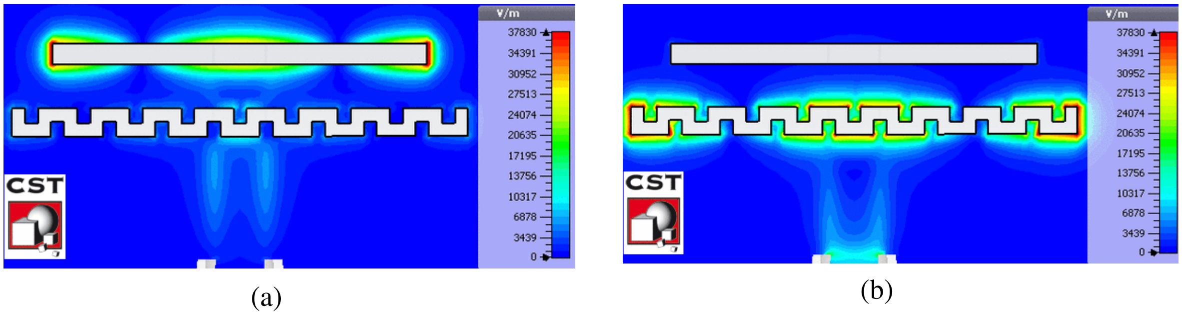

Figure 2. Simulated electric field distributions over the two resonators at the resonant frequencies: (a) At 8.2 GHz. (b) At 5.78 GHz.

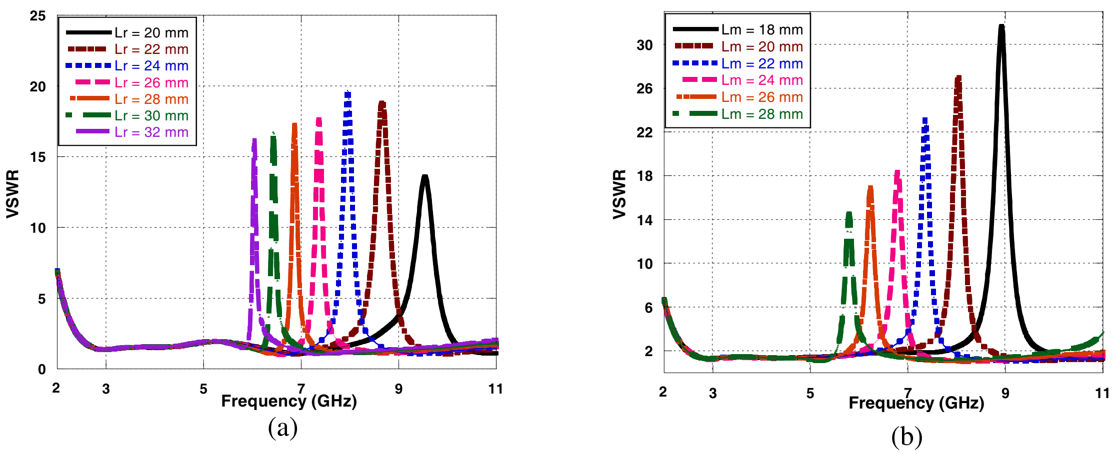

Figure 3. Simulated VSWR for various lengths of the resonator: (a) Rectangular microstrip length study. (b) Meander line length study.

notch frequency, when changing the length of the meander line resonator L_m from 18 to 28 mm. It is observed from these graphs that the notched frequency can be significantly tuned by varying the length of L_r and L_m.

3. RESULTS AND DISCUSSIONS

The proposed dual band-notched antenna has been fabricated and measured for validation purposes. Photographs of the top and bottom views of the fabricated prototype are shown in Fig. 4. The measured and simulated VSWR of the proposed antenna and the reference are shown in Fig. 4(c). A good agreement is observed between the measured and simulated data. This shows that the coupling between the two resonators is not significant. The rejection levels at the notches are higher and better than other recently published techniques [7, 8]. Moreover, the antenna without the resonators is also simulated and fabricated as a reference. Fig. 4(d) shows the simulated total efficiencies of the proposed antenna and the reference. A relatively flat and constant efficiency is observed over the UWB, except at the two desired notched bands which have significant reductions in the total efficiency.

The measured dual band-notched antenna realized gain in the direction of $\varphi = 0°$ and $\theta = 0°$ (at front side) is depicted as a function of frequency in Fig. 5(a) and compared to the reference UWB antenna realized gain at the same direction. The measured realized gain shows that there is about 15 dB gain suppression at the two notched bands between the proposed and reference antenna.

The measured group delay of two identical antennas in the face-to-face orientations with a separation distance of 54 cm to analyze the dispersion of the proposed antenna is shown in Fig. 5(b). The result shows a flat group delay except at the notched bands while the group delay of the reference

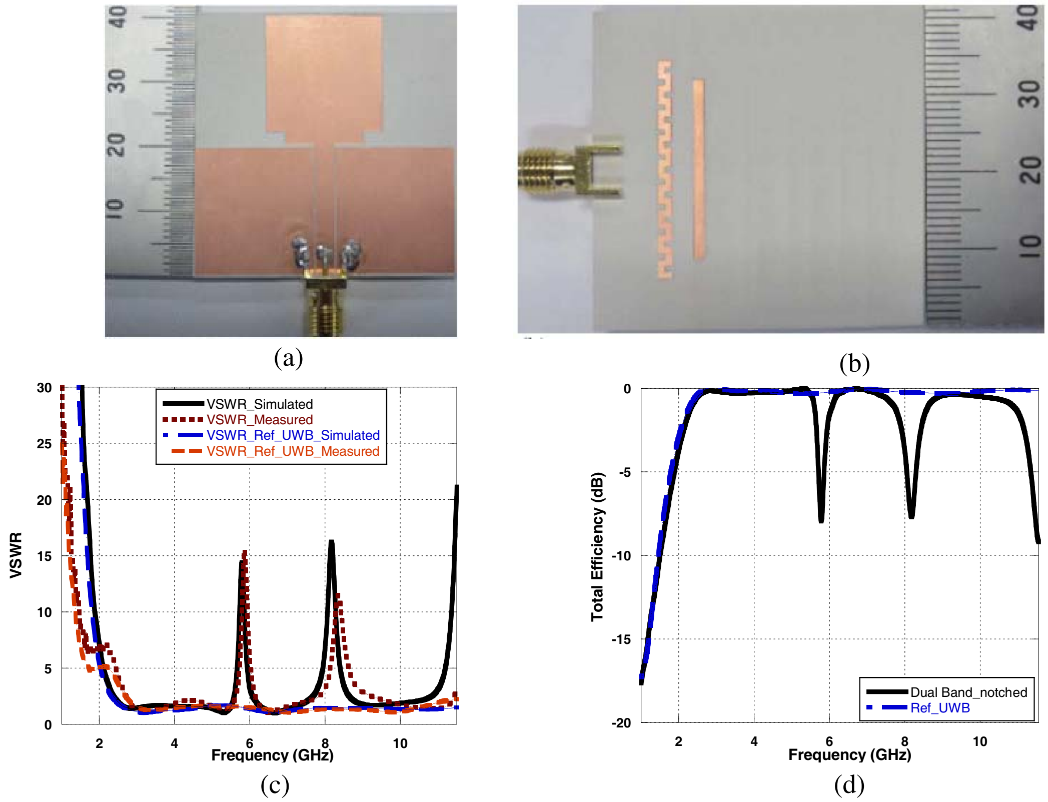

Figure 4. Photographs of the proposed fabricated dual band-notched antenna, VSWR, and efficiencies: (a) Top layer. (b) Bottom layer. (c) Measured and simulated VSWR. (d) Simulated total efficiencies.

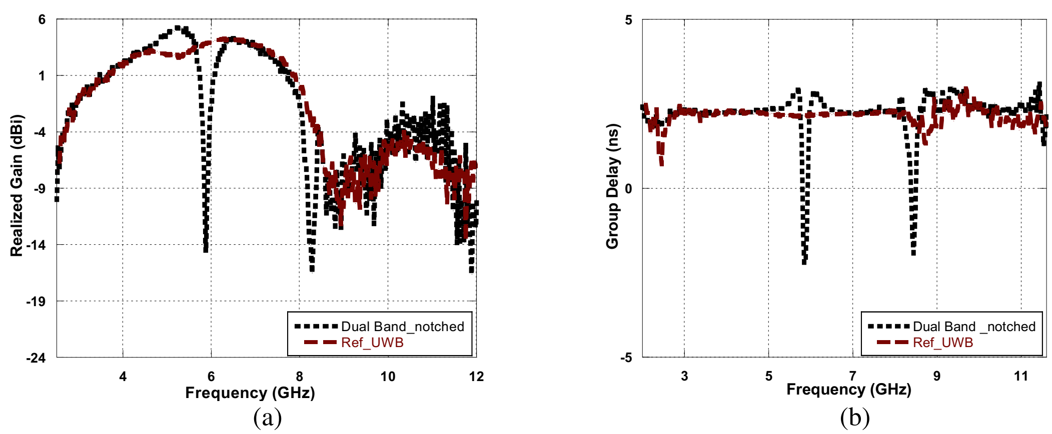

Figure 5. Measured realized gains and group delays of the proposed dual band-notched antenna and the reference UWB antenna: (a) Measured Realized gains. (b) Measured group delays.

antenna is stable over the entire frequency band of operation. Therefore the proposed antenna is convenient for transmitting and receiving UWB pulse with a very small distortion.

Figure 6 shows a comparison between the simulated and measured normalized radiation pattern results of the proposed dual band-notched UWB antenna at selected frequencies (3, 5, 7.5, 10.5 GHz) over the operating broadband. It is obvious that the radiation patterns in the E (yz-plane) and H (xz-plane) planes are stable over the whole operating frequency range and confirm the desired beams of an omnidirectional pattern of a monopole antenna. However, there are slight distortions at 10.5 GHz in the E-plane pattern; these ripples are due to using an L-shaped semi-rigid cable in the E-plane measurements, feed line connector, and coaxial cable.

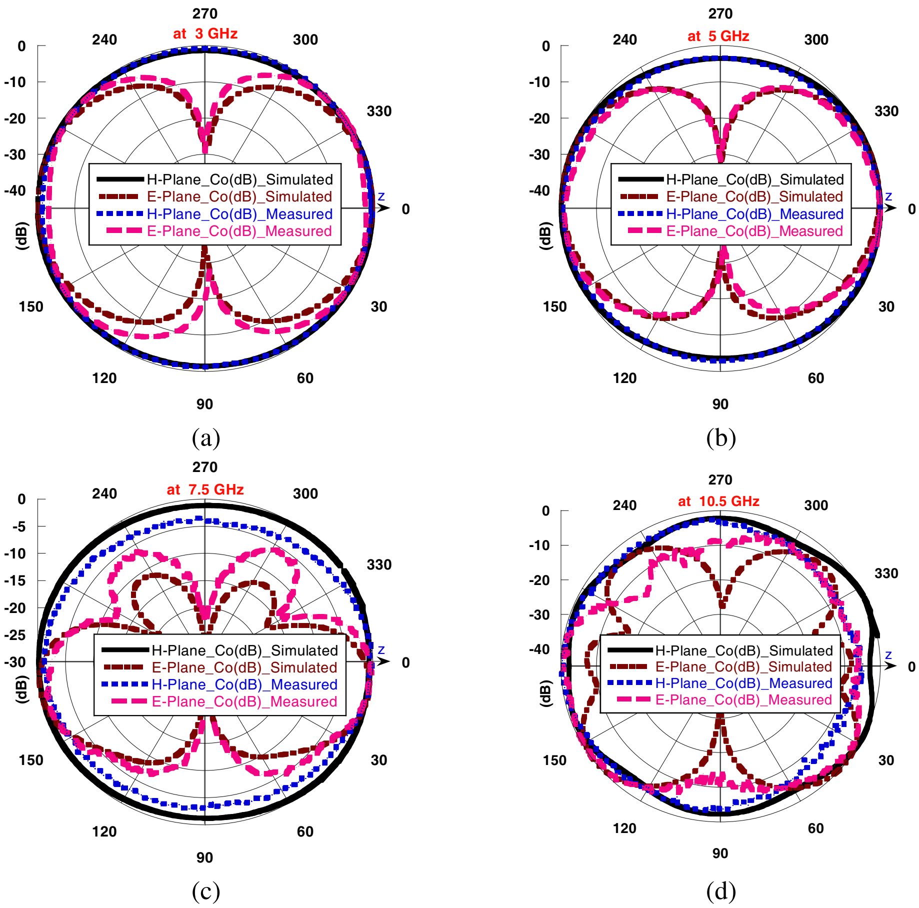

Figure 6. The proposed antenna normalized radiation pattern results. (a) At 3 GHz. (b) At 5 GHz. (c) At 7.5 GHz. (d) At 10.5 GHz.

4. CONCLUSION

In this letter, the design of a novel compact dual band-notched antenna for UWB applications is presented, fabricated, and measured for the validation purposes. In this simple design, two reject bands at the WLAN (5.725–5.825 GHz) and ITU (8.025–8.4 GHz) are successfully achieved by incorporating the rectangular and meander line microstrip resonators. Furthermore, the radiation patterns are very stable over the operating frequency range except at the intended notches.

ACKNOWLEDGMENT

This work is supported by the Mission Department of the Egyptian Ministry of Higher Education (MOHE) and Egypt-Japan University of Science and Technology (E-JUST). The authors would like to thank the E-JUST Center, Kyushu University for supporting the facilities for the simulation, fabrication, and measurements of this research.

REFERENCES

1. Abbas, S. M., Y. Ranga, Anand K. Verma, and K. P. Esselle, "A simple ultra wideband printed monopole antenna with high band rejection and wide radiation patterns," *IEEE Transactions on Antennas and Propagation*, Vol. 62, No. 9, 4816–4820, Sep. 2014.

2. Wu, Z.-H., F. W., X.-W. Shi, and W.-T. Li, "A compact quad band-notched UWB monopole antenna loaded one lateral L-shaped slot," *Progress In Electromagnetics Research*, Vol. 139, 303–315, 2013.
3. Lee, D. H., H. Y. Yang, and Y.-K. Cho, "Ultra-wideband tapered slot antenna with dual band-notched characteristics," *IET Microwave Antennas Propagation*, Vol. 8, No. 1, 29–38, 2014.
4. Trad, I. B., J. M. Floch, H. Rmili, L. Laadhar, and M. Drissi, "Planar elliptic broadband antenna with wide range reconfigurable narrow notched bands for multi-standard wireless communication devices," *Progress In Electromagnetics Research*, Vol. 145, 69–80, 2014.
5. Peng, L. and C.-L. Ruan, "UWB band-notched monopole antenna design using electromagnetic-bandgap structures," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 59, No. 4, 1074–1081, 2011.
6. Nouri, A. and G. R. Dadashzadeh, "A compact UWB band-notched printed monopole antenna with defected ground structure," *IEEE Antennas and Wireless Propagation Letters*, Vol. 10, 1178–1184, 2011.
7. Satyanarayana, B. and S. Mulgi, "Design of planar band-notched monopole antenna for 2.4 GHz WLAN and UWB applications," *Microwave and Optical Technology Letters*, Vol. 5, No. 1, 249–2501, 201.
8. Zhang, Y.-P. and C.-M. Li, "Design of small dual band-notched UWB slot antenna," *Electronics Letters*, Vol. 51, No. 22, 1727–1728, 2015.
9. Chen, L., Y.-F. Liu, and P.-C. Wu, "Design of compact asymmetric coplanar strip-fed UWB antenna with dual band-notched characteristics," *Progress In Electromagnetics Research Letters*, Vol. 47, 103–109, 2014
10. Kalteh, A. A., G. R. Dadash Zadeh, M. Naser-Moghadasi, and B. S. Virdee, "Ultra-wideband circular slot antenna with reconfigurable notch band function," *IET Microwave Antennas Propagation*, Vol. 6, No. 1, 108–112, 2012.
11. Hong, J.-S. and M. J. Lancaster, *Microstrip Filters for RF/Microwave Applications Theory Analysis and Design*, 1st Edition, Wiley & Sons, New York, 2001.
12. CST Microwave Studio, ver. 2015, Computer Simulation Technology AG, Japan, AET, 2015.