International Journal of Internet, Broadcasting and Communication Vol.12 No.2 83-89 (2020)
http://dx.doi.org/10.7236/IJIBC.2020.12.2.83

IJIBC 20-2-12

Open Ended Folded-Slot Antenna with a Wide n-Shaped Slot for Ultra-Wideband Applications

Jin-Ha Yoo and Young-Soon Lee*

The affiliated institute of Electronics and Telecommunications Research Institute (ETRI), Senior Researcher, Korea
**Department of Electronic Engineering, Kumoh National Institute of Technology, Professor, Korea*
*yjh265@nsr.re.kr, *yslee@kumoh.ac.kr*

Abstract

A microstrip feedline based open ended folded-slot antenna is proposed for ultra-wideband (UWB) applications. The prototype of the proposed antenna is fabricated on the FR4 dielectric substrate. The proposed antenna has a wide n-shaped slot that is useful for designing circuit components on the same printed circuit board (PCB) as that of the radio frequency (RF) modules. The proposed antenna use two kinds of slots as radiators, and each slots have different characteristics because of the different type of ends of the slot. The wideband characteristic can be obtained by resonances of each slot which are occurred at different frequencies. The measured impedance bandwidth ($S_{11} \leq -10$ *dB) is 2.9–11.56 GHz, and the antenna peak gain is 2–4 dBi over the UWB range. The antenna has a stable omni-directional radiation pattern and only a small group-delay variation across the UWB passband. In addition, we present a modified design with band-notched characteristics of a 5 GHz wireless local area network (WLAN) frequency band.*

Keywords: *Microstrip Feed Line; Open Ended Folded-Slot Antenna; UWB; WLAN Band-Notched; n-Shaped Slot*

1. Introduction

In order to use various communication services, the bandwidth of the antenna must be broadband [1-2]. In broadband communication, UWB systems have attracted considerable attention owing to wireless communication applications such as thru-wall sensor, distance detection, and wireless UWB. In UWB systems, the antenna design is recognized to be a key technology as there is a need for an antenna to have characteristic omni-directional radiation patterns with a high gain, a low group delay, and a printed type for commercial use [3-6]. Therefore, there have been several studies involving the design of printed antennas. However, most of the research on printed UWB antennas involved individual antennas that are separated from the main printed PCB consisting of the RF modules [3-6].

In this article, we propose a printed antenna that is suitable for design involving circuit parts on the same PCB of RF modules. We use half-wavelength folded-slot antenna with a wide n-shaped slot for UWB applications.

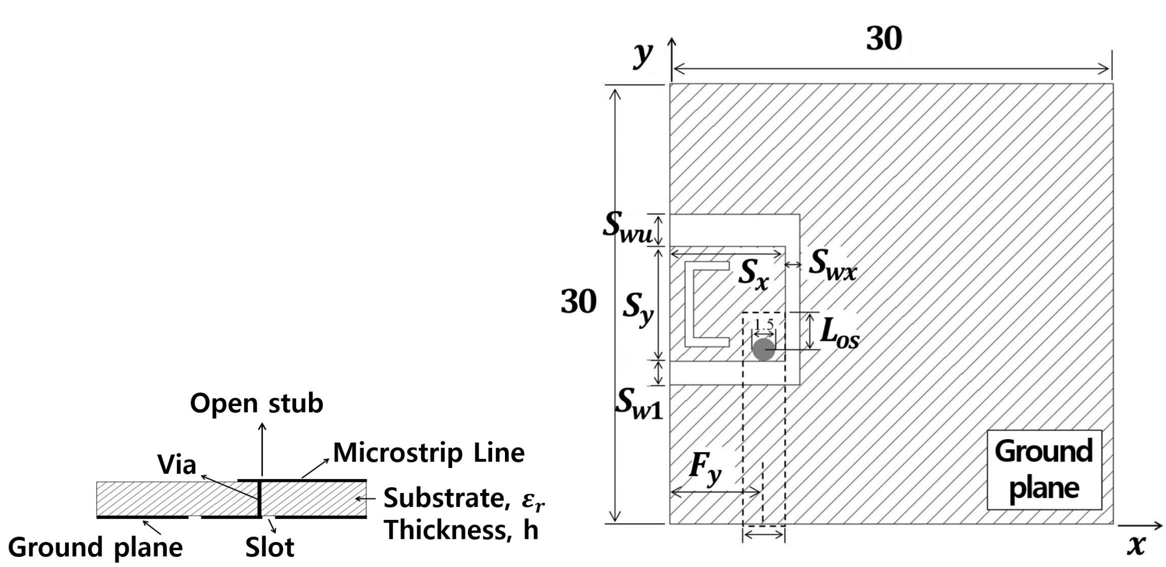
Manuscript Received: March. 13, 2020 / Revised: March. 18, 2020 / Accepted: March. 23, 2020
Corresponding Author: yslee@kumoh.ac.kr
Tel: +82-10-3826-4810, Fax: +82-54-478-7501
Professor, Department of Electronic Engineering, Kumoh National Institute of Technology, Korea

In [7], to reduce the length of the conventional λg folded-slot antenna and enhance its impedance bandwidth, the authors proposed a half-guided-wavelength (λg /2) folded-slot antenna that is cut at the finite ground plane of the PCB. Because a reduction in the size and position of the antenna at the finite ground edge can increase the space available to accommodate other circuit components, the choice for the antenna proposed in [7] is believed to be suitable for designing printed antennas with circuit parts on the same PCB. However, the impedance bandwidth ($S_{11} \leq -10$ dB) of the antenna in [7] is 2.63 - 7.27 GHz, where three resonant frequencies are observed at 3.2, 4.6, and 6.17 GHz. Therefore, a fourth resonant frequency is also needed at approximately 9 GHz for UWB applications, which cover the range 3.1 - 10.6 GHz. In order to obtain the fourth resonant frequency, a wide n-shaped slot was etched on the ground plane surrounded by the λg /2 folded slot in [7].

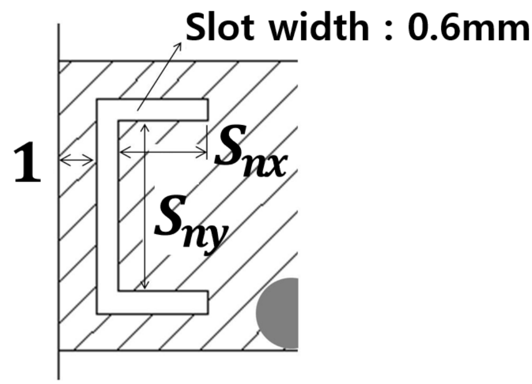
2. Antenna Design

The configuration of the proposed antenna is shown in Figure 1. The antenna is similar to a λg/2 folded-slot antenna [7], except both n-shaped slots etched on the ground plane surrounded by a λg/2 folded-slot and open stub of the microstrip feed line for impedance matching over the UWB frequency range. In Figure 1, the important parameters required for an optimum design are shown. They are as follows: The length of the open stub of Los, which is the distance from the center of the conduction via to the open end of the feed line, is important for better impedance matching. The slot lengths Sx and Sy and the slot widths Swl and Swu of the open ended folded-slot affect the low frequency band, as mentioned in [6], whereas the slot lengths Snx and Sny and the slot width Snw of the n-shaped slot affect the high frequency band as mentioned earlier.

We designed the antenna and fabricated it on a low-cost FR4 PCB with a dielectric constant of $\varepsilon_r = 4.2$, thickness of 1.6 mm, loss tangent tan σ = 0.02, and overall size of 30 × 30 mm^2 .The final optimum design parameters are as follows: Los = 2.8 mm, Sx = Sy = 7.8 mm, Swl = 1.6 mm, Swy = 2.2 mm, Snx = 2.4 mm, Sny = 4.6 mm, and Snw = 0.6 mm. Based on the optimum design, we refer to the proposed n-shaped slot as a "wide n-shaped slot", because the horizontal length Sny of the slot is longer than its vertical length Snx. The prototype antenna was fabricated according to the aforementioned design results and its photograph is presented in Figure 2.



(a) (b)



(c)

Figure 1. Structure of the proposed antenna
(a) Side view (b) Bottom view (c) Enlarged view of wide n-shaped slot

(a) (b)

Figure 2. Photograph of the fabricated antenna
(a) Top view of microstrip feed line (b) Bottom view of the ground plane

3. Results and Discussion

To verify the validity of the design parameters, the simulation and measurement results of S_{11} for the proposed antenna are compared and shown in Figure 3. It can be seen that the two results are relatively well matched. The simulated input impedance bandwidth is 3.05–10.95 GHz, whereas the measured bandwidth is 2.9–11.56 GHz. As seen in Figure 3, the fourth resonant frequency in the measured results is observed at approximately 9 GHz because of the wide n-shaped slot, where the outer perimeter of 11.8 mm corresponds to about $\lambda g/2$ at 9 GHz. It is noticeable that the measured result of 2.9–11.56 GHz is sufficient for the required frequency band of 3.1–10.6 GHz. This improvement in the impedance bandwidth is believed to be due to the introduction of the open stub as well as the wide n-shaped slot in conjunction with the open ended folded-slot.

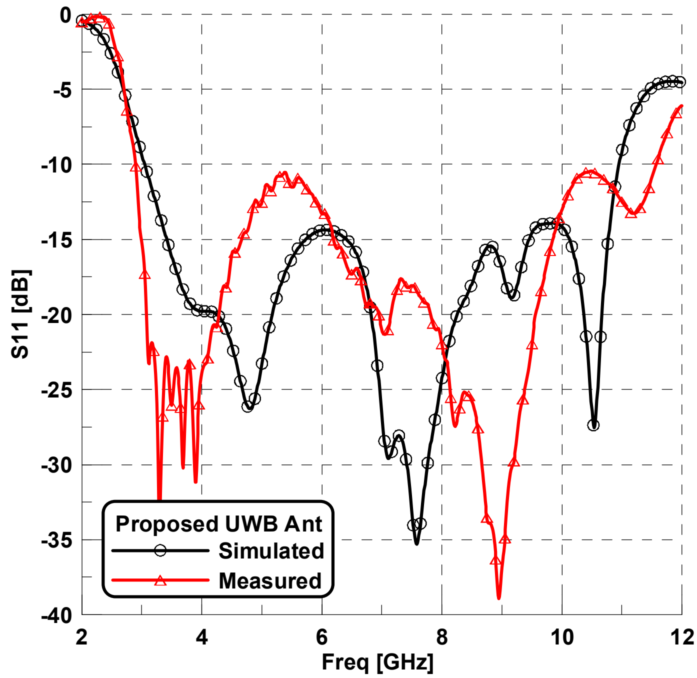
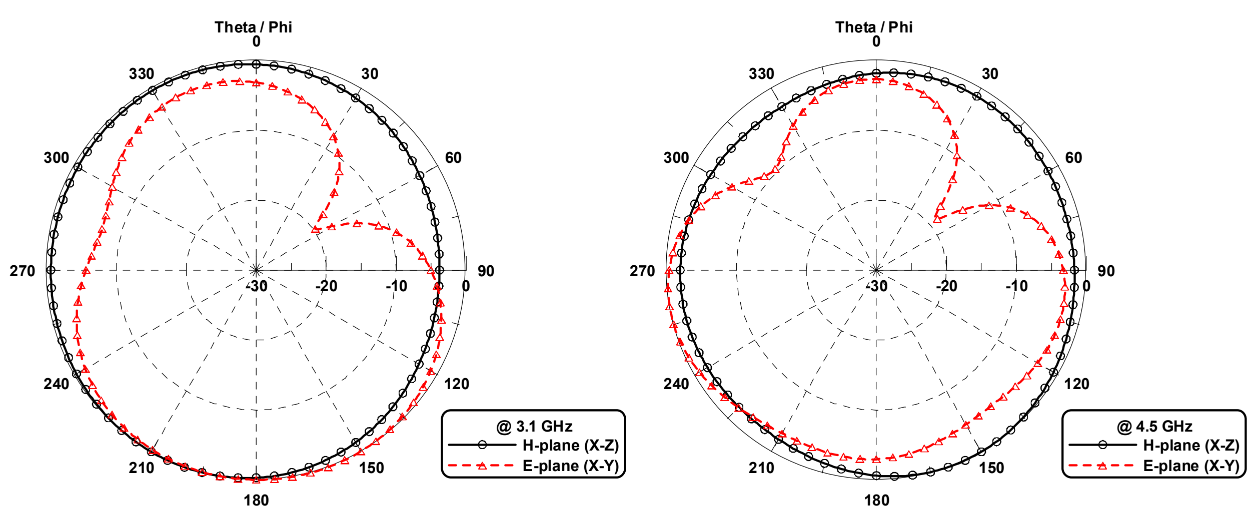
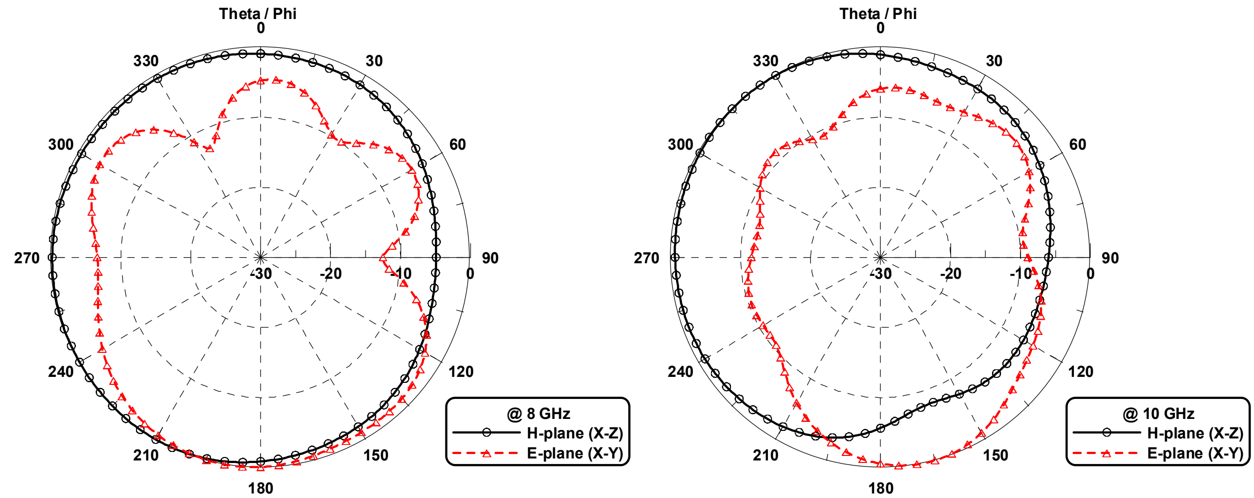


Figure 3. Simulated and measured S_{11} response of the proposed antenna

In Figure 4, we plotted the measured radiation patterns of the proposed antenna in both the H-plane (x-z plane) and E-plane (x-y plane) at the four passband frequencies of 3.1, 4.5, 8, and 10 GHz. For commercial purposes, it can be seen that the antenna has a good omni-directional radiation patterns in the H-plane (x-z plane), which are relatively stable in the entire frequency band. By means of simulations we can show that the antenna peak gain is 2–4 dBi over the UWB range.



(a) (b)



(c) (d)

Figure 4. Measured radiation patterns
(a) 3.1 GHz, (b) 4.5 GHz, (c) 8 GHz, (d) 10 GHz

Moreover, low group-delay characteristics in the time domain are required for efficient wireless UWB communication over a short distance. For time-domain performance analysis, we simulated the group-delay for two identical prototype antennas that are isolated by a distance of 30 mm. As the output power of the vector network analyzer (VNA) used to measure group-delay is generally small, we set the distance between two identical UWB antennas as 30 mm. The simulated and measured plots of group delay in the proposed antenna are presented in Figure 5, and the UWB band variation observed was less than 1 ns.

The UWB frequency band includes the 5 GHz WLAN band, which is the most commercially used band. Therefore, to reduce any existing interference caused by WLAN systems operating at 5.2 GHz and 5.8 GHz, we modified the design for the feed line as shown in Figure 6.

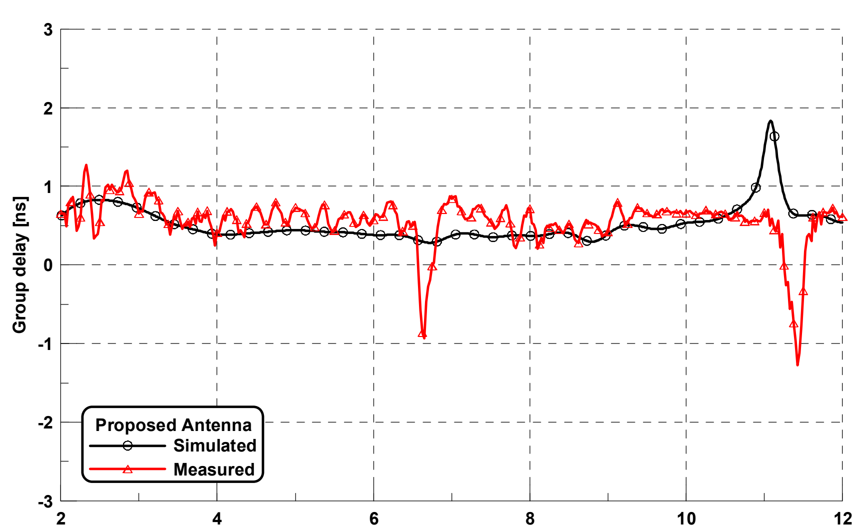


Figure 5. Measured and simulated group-delay in the time domain

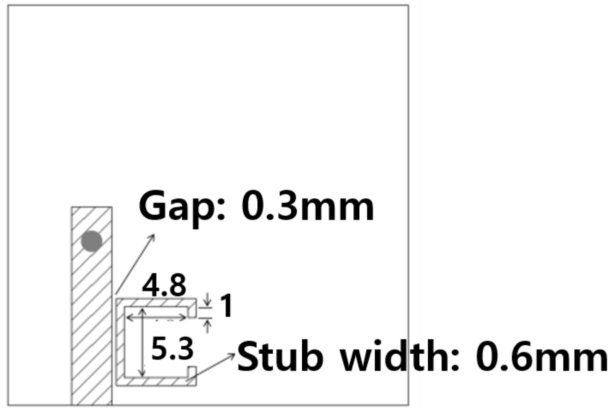


Figure 6. Top view of modified structure for band-notched characteristics

In this design, we only placed a single C-shaped metallic stub adjacent to the feed line, while in [8-9], two C-shaped stubs were attached near the feed line. At the band-notch frequency, the strips act as short-circuit to the input microwave energy [10]. The total circumference of the C-shaped stub was assumed to approximately 18 mm to enable it to be nearly equal to λg /2 at 5.5 GHz

In Figure 7, we show a comparison of the simulated and measured results of S_{11} for the modified antenna with a single C-shaped stub. As seen in this figure, a band-notch characteristic of 4.9–6 GHz ($S_{11} \leq$-10 dB) is present in the measured results. Therefore, we can reduce interference from existing WLAN systems even though we use only a single C-shaped stub.

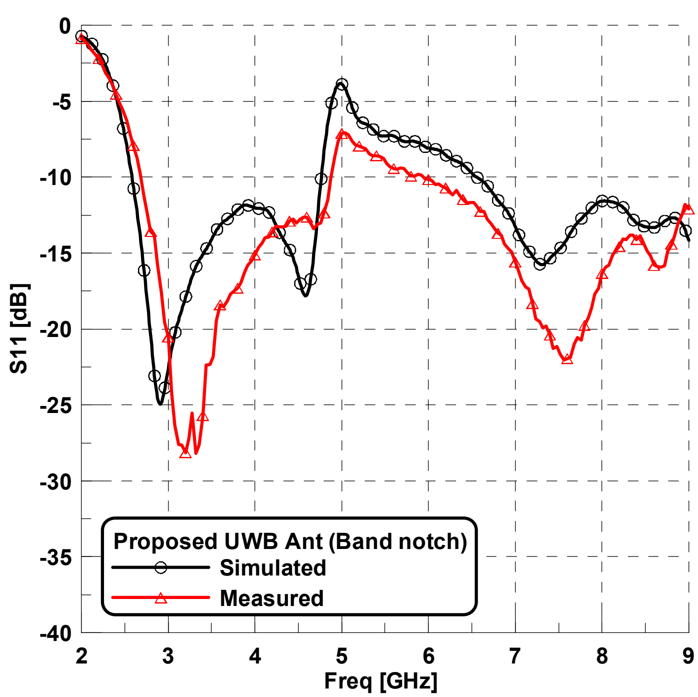


Figure 7. Simulated and measured input losses for the modified antenna with C-shaped

4. Conclusion

In this study, we designed, fabricated, and measured a microstrip feedline based printed, open ended, and a folded-slot antenna with a wide n-shaped slot that is useful for the design of RF module components that lie on the same PCB. *The wideband characteristic can be obtained by resonances of each slot which are occurred at different frequencies.* The proposed antenna is expected to provide more space for components because its radiation slot component (8.8 × 11 mm^2) occupies merely 11.34% of the ground plane (30 × 30 mm^2). Furthermore, *the measured impedance bandwidth (*$S_{11} \leq$ *-10 dB) is 2.9–11.56 GHz, and the antenna gain is 2–4 dBi over the UWB range.* we envisage that the proposed UWB will be used commercially owing to its good omni-directional radiation patterns and only a small group-delay variation over the UWB range. The modified design that has been presented offers a band notch from 4.9–6 GHz, and it reduces interference due to existing WLAN (5.15~5.825 GHz) systems.

References

[1] D. H. Kim and G. G. Kim, "Design of Fractal Structure Wideband Antenna for 4G IMT-Advanced Access Point Applications", *The Journal of IIBC*, Vol. 14, No. 1, pp. 195-201, Feb. 2014.
DOI: http://doi.org/10.7236/JIIBC.2014.14.1.195

[2] G. J. Choe and S. W. Kang, "Implementation of Broadband Printed Sleeve Monopole Antenna", *The Journal of IIBC*, Vol. 14, No. 6, pp. 245-250, Dec. 2014.
DOI: https://doi.org/10.1109/TAP.2005.858819

[3] T. G. Ma and S. K. Jeng, "A printed dipole antenna with tapered slot feed for ultrawide-band applications", *IEEE Trans. Antennas Propag.*, Vol. 53, No. 11, pp. 3833-3836, Nov. 2005.
DOI: https://doi.org/10.1109/TAP.2005.858819

[4] H. H. Choe and S. J. Lim, "Ultrawideband compact U-shaped antenna with inserted narrow strip and inverted T-shaped slot", *Microwave Opt. Technol. Lett.*, Vol.56, No.10, pp.80-84, Oct. 2014.
DOI: https://doi.org/10.1002/mop.28566

[5] A. K. Gautam, S. Yadav and B. K. Kanaujia, " A CPW-FED compact inverted L-strip UWB microstrip antenna" *Microwave Opt. Technol. Lett.*, Vol.55, No.7, pp.1584-1589, Jul. 2013.
DOI: https://doi.org/10.1002/mop.27651

[6] M. C. Tang, T. Shi and R. W. Ziolkowski, " Planar Ultrawideband Antennas With Improved Realized Gain Performance" *IEEE Trans. Antennas Propag.*, Vol.64, No.1, pp.61-69, Jan. 2016.
DOI: https://doi.org/ 10.1109/TAP.2015.2503732

[7] J. H. Yoo and Y. S. Lee, "Bandwidth enhancement and size reduction of microstrip-fed folded-slot antenna", *Microwave Opt. Technol. Lett.*, Vol. 55, No. 10, pp. 2248-2251, Oct. 2013.
DOI: https://doi.org/10.1002/mop.27829

[8] D. H. Lee, H. Y. Yang and Y. K. Cho, "Design and analysis of tapered slot antenna with 3.5 / 5.5 GHz band-notched characteristics", *Progress In Electromagnetics Research B*, Vol. 56, pp. 347-363, 2013.
DOI: https://doi.org/10.2528/PIERB13092702

[9] G.G. Lele He, B. Hu and X. Cong, "Novel dual band-notched UWB antenna with T-shaped slot and CSRR structure", *Microwave Opt. Technol. Lett.*, Vol. 57, No. 7, pp. 1584-1590, Jul. 2015.
DOI: https://doi.org/10.1002/mop.29175

[10] R. Kumar, R. K. Khokle and R. V. S. Ram Krishna, "A horizontally polarized rectangular stepped slot antenna for ultra wide bandwidth with boresight radiation patterns.", *IEEE Trans. Antennas Propag.*, Vol. 62, No. 7, pp. 3501-3510, Jul. 2014.
DOI: https://doi.org/10.1109/TAP.2014.2321132