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Research Article

An Open Slot Antenna with Bandwidth Extension for WLAN/UWB Applications

Jing-Ya Deng,[1,2] Tian-Qi Fan,[1] Yan Zhang,[2] Xiang Wen,[2] Guo-Qiang Liu,[3] and Li-Xin Guo[1]

[1] *School of Physics and Optoelectronic Engineering, Xidian University, Xi'an, China*
[2] *Institute of China Electronic System Engineering Corporation, Beijing, China*
[3] *Beijing Institute of Spacecraft System Engineering, Beijing, China*

Correspondence should be addressed to Jing-Ya Deng; jydeng2011@126.com

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An open slot antenna with extended bandwidth for WLAN and UWB applications is proposed. The radiating structure is composed of a rectangular microstrip patch antenna exciting an L-shaped slot etched on the ground plane. The feed position is optimized to get better impedance match for the higher range of the UWB spectrum, while a step in the slot, realized in the ground plane, is employed to extend the lower limit of the bandwidth so as to cover the 2.4 GHz WLAN frequency band. Using these design solutions the antenna bandwidth is successfully extended to 140% so as to cover both the WLAN and the UWB spectrum.

1. Introduction

In recent years, the wideband antennas have been widely used in wireless communication and radar systems. The development of high performance radio systems for multistandard local area networks [1, 2], the monitoring of the automotive transportation [3, 4], the remote screening of biological activities [5–7], and the analysis of the ground subsurface [8–10], as well as through-the-wall radar imaging [11], require the adoption of broadband antennas. In particular, the UWB communication systems have attracted considerable interest from both the academic and the industrial sectors, owing to their good characteristics, including low cost, low complexity, and extremely high data rate useful for short range communications. Being important components of UWB systems, the UWB antennas are nowadays a very hot topic frequently discussed in scientific papers. In the thousands of papers about UWB antennas, printed slot antennas are frequently considered due to their attractive characteristics such as the low profile, the wide bandwidth, the compact size, and the ease of manufacturing. A microstrip fed patch antenna with a quarter wave open slot etched on the ground plane was proposed in [12]. In this paper, a broadened bandwidth of about 94%, which is much wider than that of the traditional patch antennas, but insufficient for the UWB applications, has been obtained. A rotated patch is introduced in [13] to enhance the bandwidth of the antenna to 3.1–10.6 GHz so as to cover the UWB applications. T-shaped stub extended from the patch [14] and truncated corner of the patch [15] are also presented to increase the bandwidth. Some novel structures, such as dipolar planar radiating structures, are also studied for UWB systems. For example, a low-profile printed drop-shaped dipole antenna [16] was reported to obtain interesting radiative performances in both frequency and time domain. Specifically, such antenna can be adopted to realize compact array antennas. However, only few of the mentioned papers consider the potential applications of the antennas in the WLAN systems working in the 2.4–2.48 GHz frequency band.

In this paper, a wideband microstrip patch antenna, integrating an open-ended L-shaped slot on the ground plane, for WLAN and UWB applications is proposed. The feed position is optimized to get better impedance matching for the higher frequencies of the UWB spectrum, while a step in the slot on the ground plane is employed to extend the lower limit of the frequency band to 2.4 GHz WLAN band. The antenna performances are analyzed and discussed, while a prototype has been fabricated and measured. The obtained results show

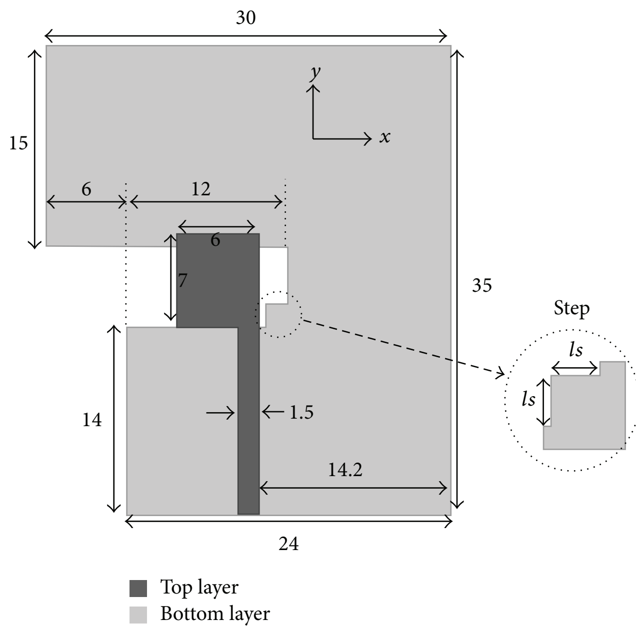


Figure 1: Geometry of the proposed antenna (all the geometrical dimensions are expressed in millimeter).

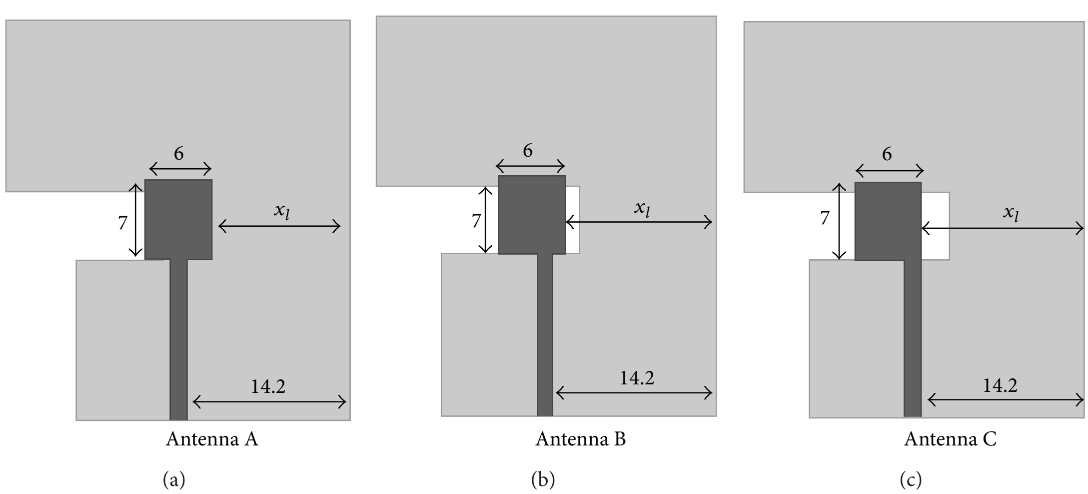


Figure 2: Design solutions adopted to excite the patch antenna.

that the bandwidth has been successfully broadened and that the proposed antenna is a good candidate for both WLAN and UWB systems.

2. Design and Optimizations

The geometry of the proposed antenna is shown in Figure 1. The antenna is printed on a low cost FR4 substrate having thickness of 1 mm, relative permittivity of 4.6, and loss tangent of 0.02. The radiating structure is composed of a microstrip patch antenna and an asymmetrically slotted ground plane. The L-shaped slot etched on the ground plane has been employed to enlarge the antenna bandwidth.

The different design solutions adopted to excite the patch are shown in Figure 2, while the numerical simulations of the corresponding S_{11} parameter are given in Figure 3. An EM simulator HFSS is used to optimize the geometry. In particular, a lumped port is set at the end of the microstrip line, while perfectly matched layers (PML) have been employed as absorbing boundary conditions to model the free-space environment. The design begins with antenna A shown in Figure 2, in which the feed position is located at the center of the radiating patch. Antenna A can cover the 2.35–6 GHz frequency band with S_{11} better than −10 dB, which is much wider than that of the traditional patch antenna, but it is insufficient for the UWB communications. To meet the bandwidth requirements of the UWB systems, the patch is moved, so the feed position is gradually transferred from the center of the patch up to its edge, as it is shown in antenna sketches B and C depicted in Figure 2. The

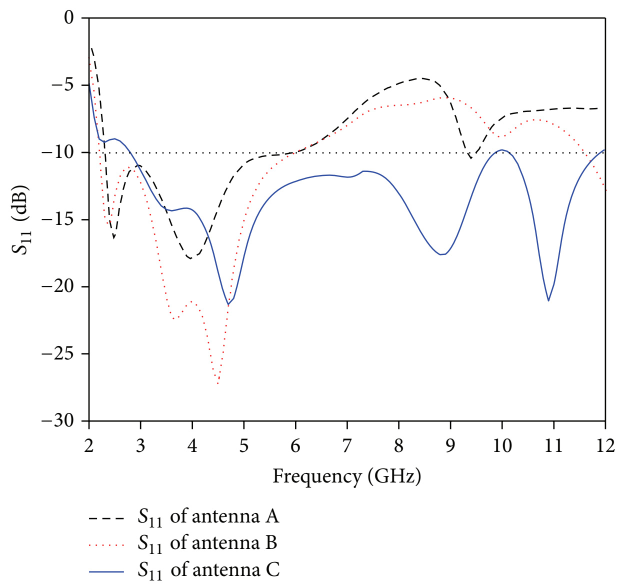
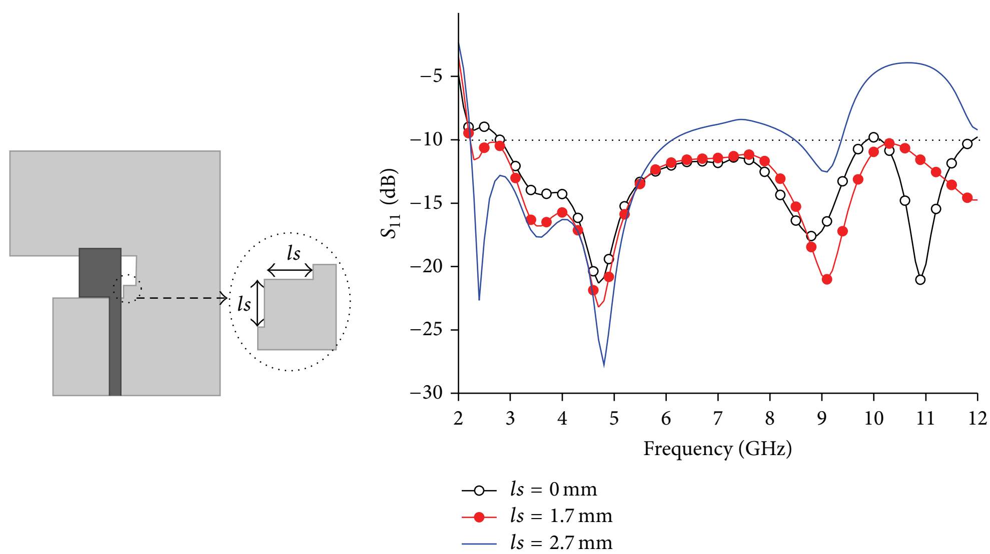


Figure 3: Magnitude of the scattering parameter S_{11} versus frequency of the antennas depicted in Figure 2.



(a) (b)

Figure 4: Magnitude of the scattering parameter S_{11} versus frequency for different values of the geometrical parameter ls.

corresponding geometrical parameters of antennas A, B, and C are reported in Table 1. From Figure 3, it can be observed that the impedance matching at the higher frequencies of the UWB spectrum is improved during the adjustment. It should be noticed that the antennas depicted in Figure 2 have no step in the ground plane as instead it is present in the antenna shown in Figure 1.

The improvement of the performance of the parameter S_{11} on high frequency, obtained by the movement of the feed position, worsens the impedance matching on the frequencies near 2.4 GHz. From Figure 3 it can be observed that antenna C can cover the entire UWB band with the parameter S_{11} lower than −10 dB from 2.8 GHz up to 12 GHz, but in any case it is not suitable for the WLAN applications at 2.4–2.48 GHz. So, a step in the ground plane having length ls, as shown in Figure 1, is introduced in antenna C to improve the impedance matching at the lower frequencies. Figure 4 shows the antenna parameter S_{11} for different values of the geometrical parameter ls. As it can be observed, the

Table 1: The key geometrical parameters of antennas A, B, and C in Figure 2.

	Antenna A	Antenna B	Antenna C
x_l (mm)	12	13.1	14.2

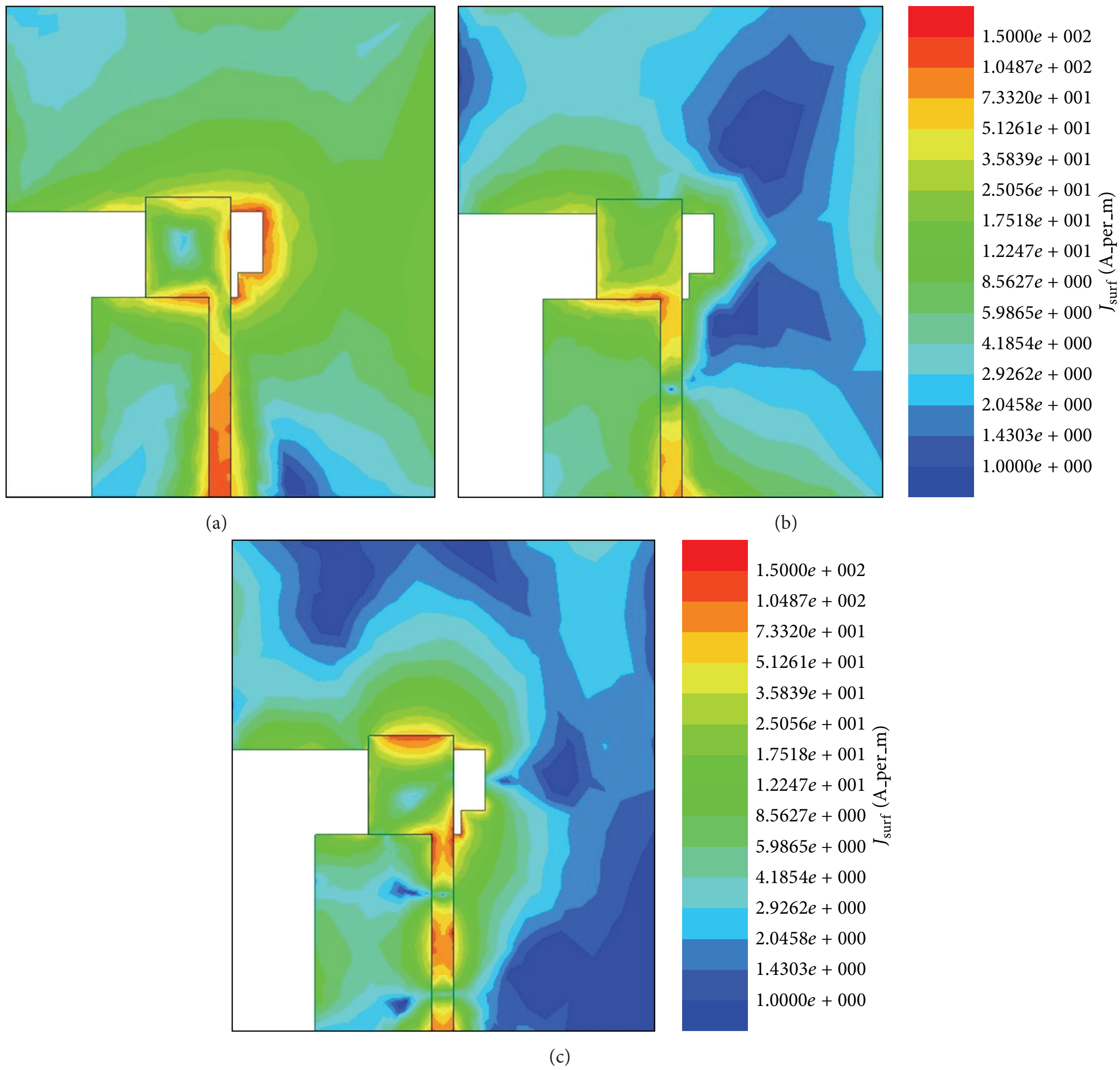


Figure 5: Surface current distributions, (a) 2.4 GHz, (b) 5 GHz, and (c) 10 GHz.

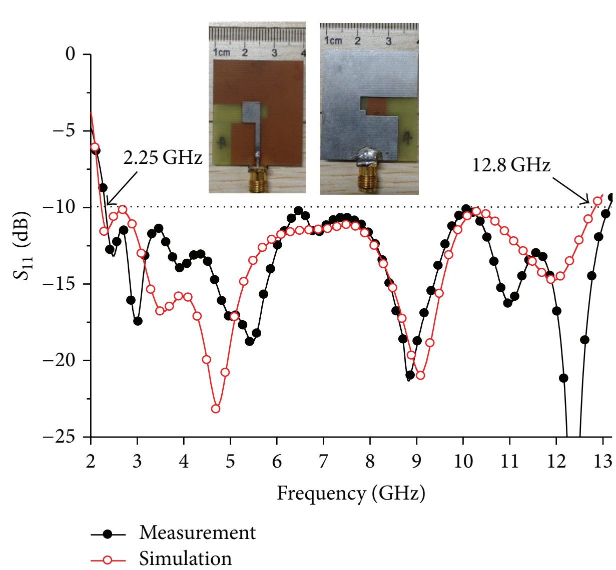


Figure 6: Magnitude of the scattering parameter S_{11} versus frequency of the proposed antenna.

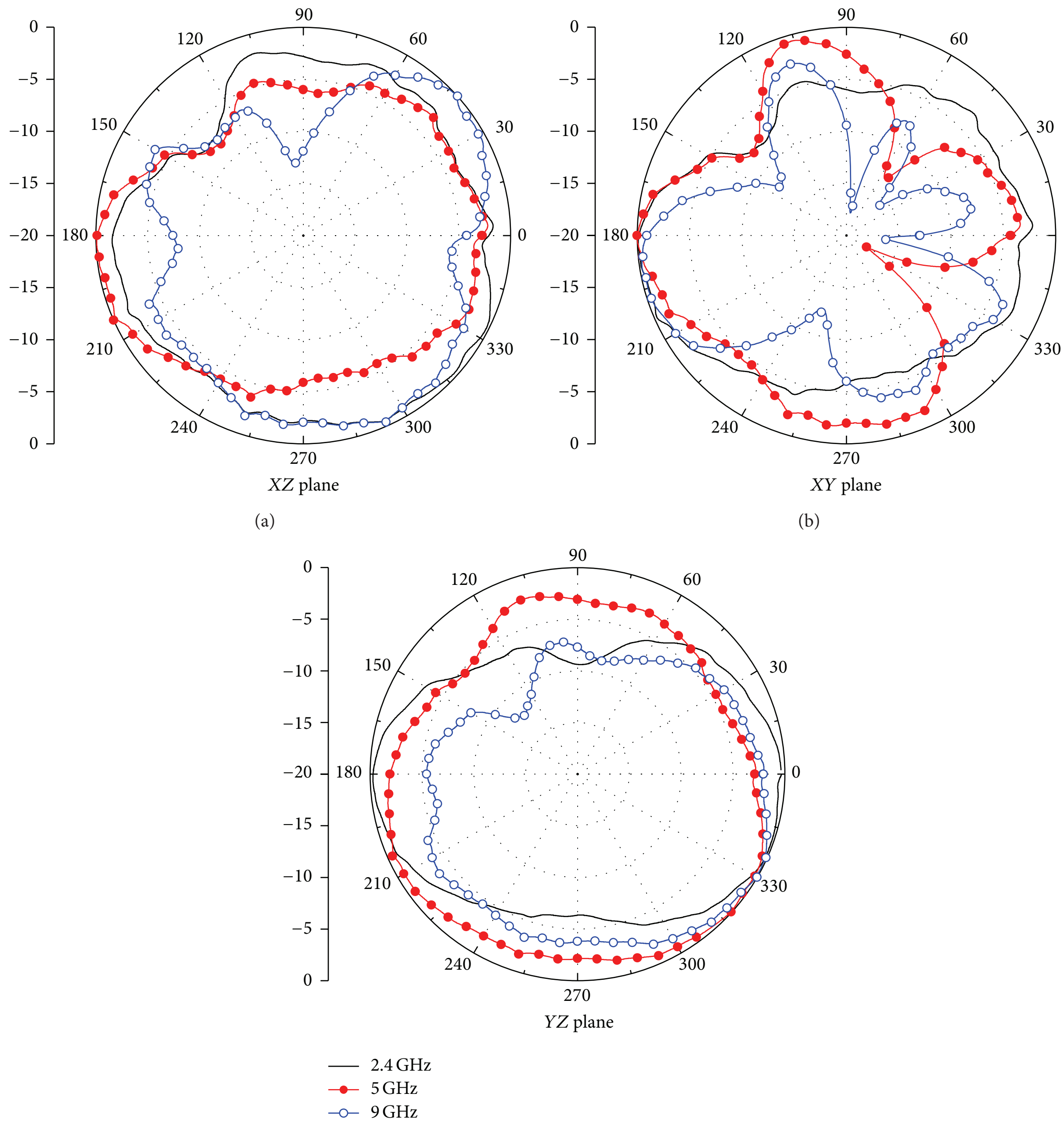


Figure 7: Radiation patterns of the proposed antenna.

impedance matching gets better at the lower frequencies, but it becomes worse at the higher frequencies when the parameter *ls* exceeds 1.7 mm. So, we choose the optimal value of 1.7 mm for *ls*. From the above considerations we can conclude that the step involved in the slotted ground plane plays an important role in the impedance matching.

To investigate about the radiation mechanisms governing the antenna behavior [17], the current distributions computed at 2.4, 5, and 10 GHz are shown in Figure 5. From this figure it appears that the electromagnetic energy emissions at the lower frequencies (2.4 and 5 GHz) are due to the L-shaped open slot. Consequently, a step with a proper *ls* value inserted in the slot can extend the current path on the ground plane near 2.4 GHz, so that the lower limit of the operation band can be extended to cover the WLAN frequency band. Finally, from Figure 5(c) it is evident that the antenna resonates on the fundamental mode of the microstrip patch near 10 GHz.

3. Measurement Results

The optimized antenna depicted in Figure 1, with ls = 1.7 mm, has been fabricated and measured. The frequency

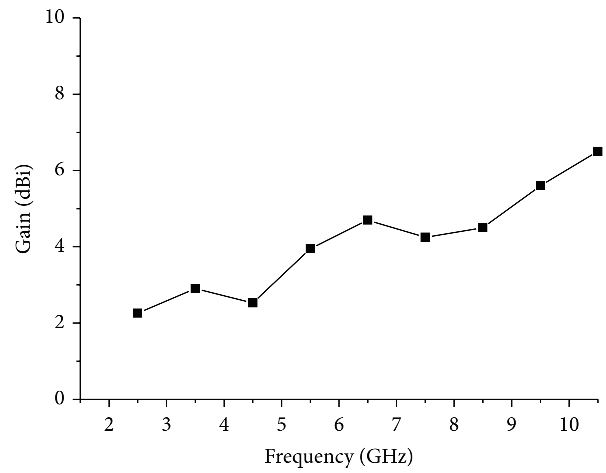


Figure 8: Gains of the optimal antenna.

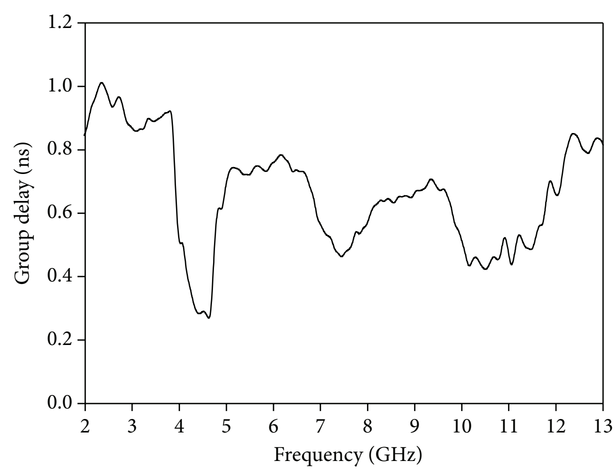


Figure 9: Group delay of the optimal antenna.

behaviors of the simulated and measured S_{11} parameter are plotted in Figure 6. A good agreement between the two curves is observed. In this way, a frequency band between 2.25 GHz and 12.8 GHz, which covers both the WLAN and the UWB frequency spectrums, is obtained. This means that the antenna bandwidth is successfully extended by moving the feed position of the radiating patch and using a step on the slotted ground plane. Figure 7 shows the measured radiation patterns of the optimized antenna at the frequencies of 2.4 GHz, 5 GHz, and 9 GHz, respectively. The antenna radiation patterns in the XZ plane are not omnidirectional, especially at 9 GHz, due to the asymmetrical ground plane. The gain of the optimized antenna varies between 2.26 and 6.5 dBi over the entire working band as reported in Figure 8.

The group delay quantifies the pulse distortion and the phase linearity of the field radiated by the antenna in the far region, so it represents a very important parameter for the UWB communications. The group delay is measured by means of two identical antennas placed at a distance of 20 cm, with the two antennas facing each other where the corresponding radiation patterns present their maximum. The maximum measured value of the group delay is less than 1 ns as it is shown in Figure 9. This means that the phases are nearly linear in the far field region and almost no pulse distortion will be caused.

4. Conclusion

A microstrip patch antenna with frequency band ranging from 2.25 GHz up to 12.8 GHz, suitable to cover the WLAN and UWB applications, has been presented. The bandwidth has been extended to 140% by optimizing the feed position of the patch and realizing a step on the slotted ground plane. The measured results show that the optimized antenna can be used successfully for both the WLAN and the UWB communication systems.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

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