Monopole Antenna with Three Branch Strips and Rectangular Slit Ground for WLAN/WiMAX Applications

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ABSTRACT

A planar monopole antenna that was developed for WLAN/WiMAX application is presented in this paper. The proposed antenna with three strips, an asymmetrical ground plane, and a rectangular slit in the ground is designed to cover the popular frequency spectrum of WLAN (wireless local area network) bands and WiMAX (Worldwide Interoperability for Microwave Access) bands. The proposed antenna, which is capable of wideband operation, is fed by a strip line and fabricated on an FR-4 substrate. The obtained numerical results agree well with the experiment data. It was validated that the configuration can meet the demands for the WLAN/WiMAX systems and effectively enhanced the impedance bandwidth to 9.95% for the lower band and 76.05% for the upper band for VSWR $<$ 1:2. This paper also presents and discusses the 2D radiation patterns and 3D gains according to the results of the experiment.

Keywords: *antenna, WLAN/WiMAX antenna, monopole antenna, triple-band operation*

1. INTRODUCTION

The demand for low-profile, lightweight, and low-cost broadband antennas has increased with the widespread deployment of short-distance wireless communications. The wireless local area network (WLAN) is one of the most popular communication systems that operate in the 2.4GHz and 5GHz bands. Since 1999, the WLAN standards, including IEEE 802.11a/b/g systems, were established by IEEE 802.11 Group a. WLAN 802.11b is one of the WLANs, with frequency bands that range from 2.4 to 2.484 GHz for the ISM band. Also, HIPERLAN 2 was developed for the frequency band ranges of 5.15-5.35 GHz, 5.470-5.725 GHz, and 5.725-5.925 GHz. The required frequency for 5GHz WLANs is 5.15-5.35 GHz / 5.725-5.825 GHz for IEEE 802.11a. U-NII covers the frequency band of 5.725-5.825 GHz.

Also, broadband wireless access, commonly known as WiMAX (Worldwide Interoperability for Microwave Access), which is allocated the 2.5-2.69/3.4-3.69/5.25-5.85GHz bands, is an emerging wireless communication system that can provide broadband access with large-scale coverage. The technology can reach a theoretical 30-mile coverage radius, data rates of up to 75 Mbps, and a throughtput that is close to the 1.5Mbps performance [1-2].

To achieve the purpose of using multiband and broadband antennas for WLAN/WiMAX application, much research has been reported in literature [3-4]. The currently popular antenna designs satisfy WLAN/WiMAX standards via several main methods. In this research, a monopole antenna with three branch strips for dual bands—i.e., suited to operate in both WLAN band (2.4-2.484, 5.15-5.35, and 5.75-5.85GHz) and WiMAX band (3.4-3.7, 5.15-5.35, 5.47-5.725, and 5.725-5.825GHz) applications—was designed. The details of the proposed antenna design and the experiment results are presented and discussed next.

2. ANTENNA DESIGN

The geometry of the proposed monopole antenna with three branch strips is shown in Figure 1. The total size of the proposed antenna is 37 mm x 40 mm. As shown in the figure, the antenna consists of three branch strips, an asymmetry ground plane, and a rectangular slit in the ground plane. The antenna was mainly constructed with three branch strips and fed by a microstrip line. The three branch strips were printed on an inexpensive FR4 substrate with a relative permittivity of 4.4 and a thickness of 1.0 mm. By properly calculating and carefully arranging the radiating bended strips, the capacitive and inductive effects of electromagnetic coupling were compensated for.

The ground size of the proposed antenna is 37 mm x 15 mm. The ground plane is asymmetrical at the base line of the feeding strip line. Also, a rectangular slit in the ground is introduced to obtain a WLAN/WiMAX-suitable operating bandwidth. The rectangular slit in the ground is positioned on the other side, at the three strips and on the feeding strip line. The width and length of the rectangular slit in the ground were selected for wide-impedance-bandwidth WLAN/WiMAX operation. Thus, the impedance bandwidth for the desired frequency bands can be easily achieved. To obtain the optimal parameters (lines, lengths, and gaps) of the proposed antenna for WLAN/WiMAX application, HFSS [5], a full-wave commercial EM software that can simulate a finite substrate and a finite ground structure, was used. The length and width of the strip line match the input impedance of the WLAN/WiMAX patch antenna. Therefore, the proposed antenna design can provide a wide bandwidth while retaining stable performance via the optimized geometrical parameters. The dimensions of the proposed antenna were set as follows: L_1 = 3.0 mm; L_2 = 4.0 mm; L_3 = 6.0 mm; L_4 = 7.5 mm; L_5 = 12.5 mm; L_6 = 9.0 mm; L_7 = 16.5 mm; L_8 = 1.5 mm; L_9 = 9.0 mm; L_{10} = 4.0 mm; L_{11} = 12.0 mm; L_{12} = 15.0 mm; L_{13} = 18.0 mm; W_1 = 2.0 mm; W_2 = 6.0 mm; W_3 = 1.0 mm; W_4 = 6.0 mm; W_5 = 1.0 mm; W_6 = 6.0 mm; W_7 = 8.0 mm; W_8 = 17.0 mm; W_9 = 2.0 mm; W_{10} = 4.0 mm; W_{11} = 5.0 mm; W_{12} = 3.0 mm; and W_{13} = 16.0 mm. The proposed antenna was constructed and experimentally tested, and the measured results are given in this paper.

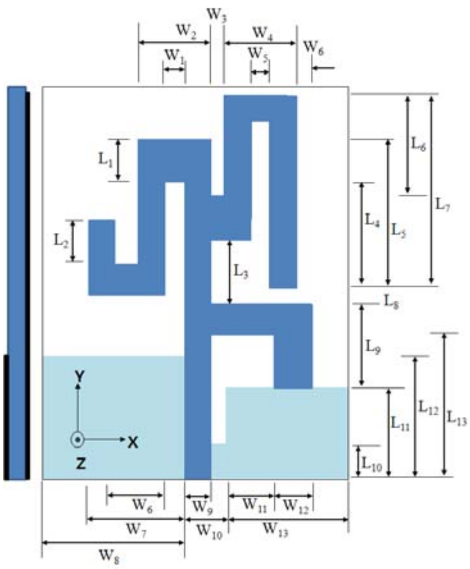


Figure 1. Configuration of the microstrip-fed monopole antenna with three strips and a rectangular slit in the ground.

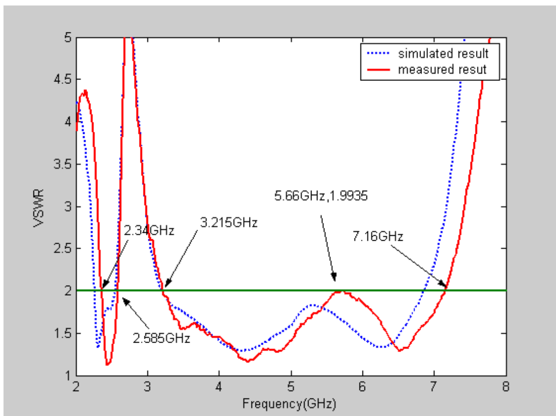
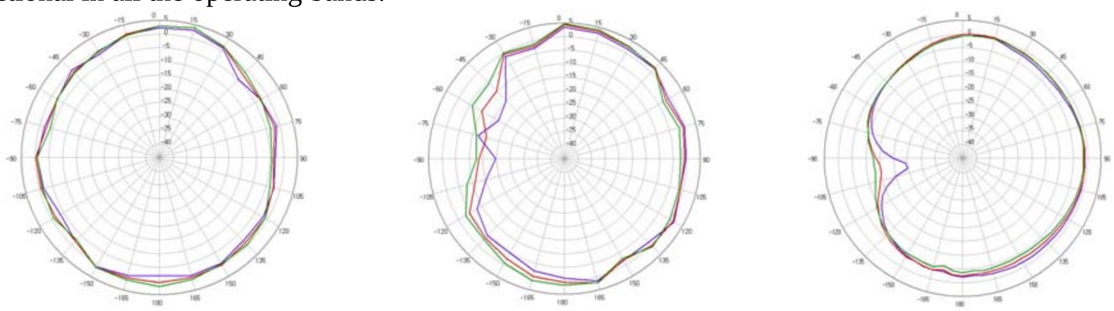


Figure 2. Simulated and measured VSWR vs. the frequencies of the proposed antenna.

3. RESULTS AND DISCUSSION

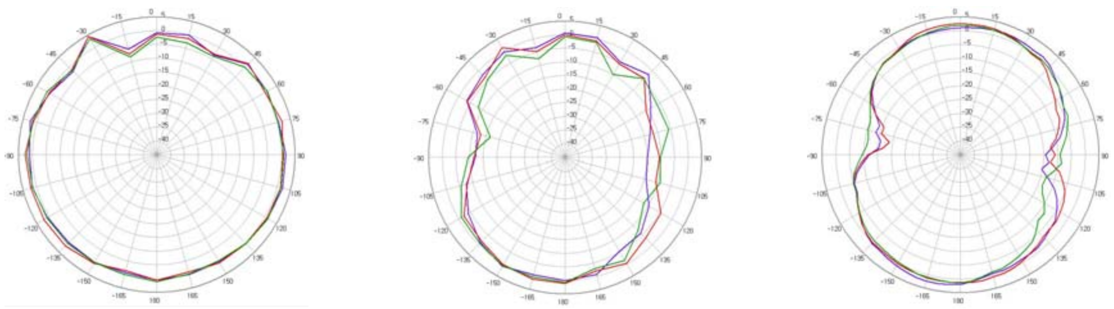
A proposed antenna was implemented, and the frequency response of the input return loss of the proposed antenna was measured with an Agilent Technologies E8362B network analyzer from Kyungnam University. The far-field radiation patterns and gains were measured with the far-field anechoic absorber from EMW Corporation. Figure 2 shows the measured and simulated VSWR for the fabricated antenna. The measured data generally agree with the simulated results. The proposed antenna can generate three separate resonant modes at about 2.46 GHz, 4.4 GHz, and 6.52 GHz to cover 2.4, 5.2, and 5.8 GHz, respectively, with good impedance matching conditions. Based on the VSWR of 1:2.0, which is acceptable for each application, the impedance bandwidth of the proposed antenna was about 245 MHz to 3,945 MHz (2.34-2.585 GHz to 3.215-7.16 GHz). The two wide-impedance bandwidths that were obtained cover the operating bandwidths of the WLAN and WiMAX bands.

Figures 3, 4, and 5 show the measured 2D far-field radiation patterns of the proposed antenna. Figure 3 (a), (b), and (c) show the 2D radiation pattern at 2.4 GHz, 2.44 GHz, and 2.48 GHz, respectively. Figure 4 (a), (b), and (c) show the 2D radiation pattern at 3.3 GHz, 3.5 GHz, and 3.7 GHz, respectively. Figure 5 (a), (b), and (c) show the 2D radiation pattern at 5.1 GHz, 5.3 GHz, 5.6 GHz, and 5.9 GHz, respectively. It can be seen that the radiation patterns were approximately omni-directional in all the operating bands.



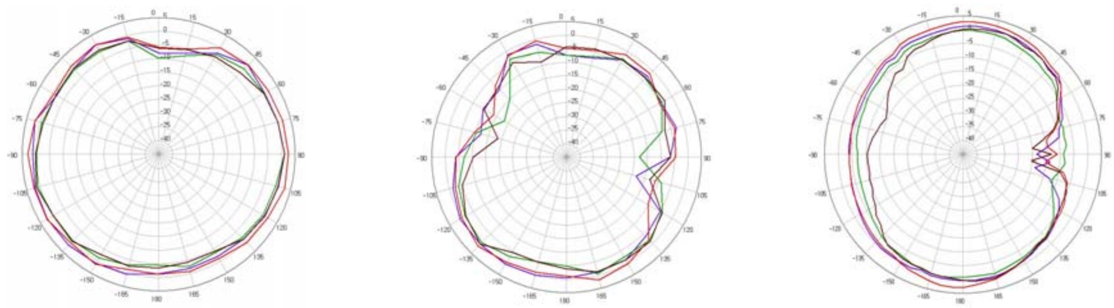
(a) x-z plane (b) y-z plane (c) x-y plane

Figure 3. Radiation patterns of the proposed antenna for wideband operation at 2 GHz bands.



(a) x-z plane (b) y-z plane (c) x-y plane

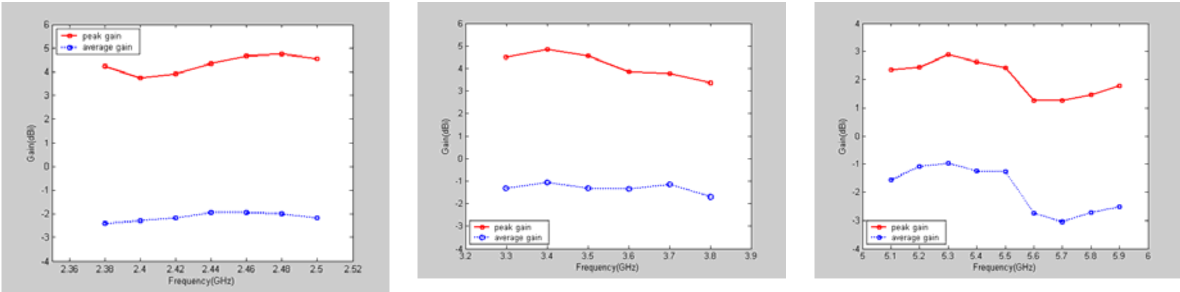
Figure 4. Radiation patterns of the proposed antenna for wideband operation at 3 GHz bands.



(a) x-z plane (b) y-z plane (c) x-y plane

Figure 5. Radiation patterns of the proposed antenna for wideband operation at 5 GHz bands.

Figure 6 (a), (b), and (c) show the 3D measured antenna peak and average gain for frequencies across the 2.4GHz, 3.5GHz, and 5GHz bands. The 2.4GHz band had an antenna peak gain level of about -0.39~4.68 dBi [Fig. 6 (a)], and the 3.5GHz band, about 0.701-4.467 dBi [Fig. 6 (b)]; and the measured antenna gain levels were about 0.523-2.884 dBi in the 5.2GHz band and about -0.557~1.221 dBi in the 5.8GHz band [Fig. 6 (c)].



(a) 2.4GHz bands (b) 3.5GHz bands (c) 5GHz bands

Figure 6. Measured antenna peak and average gains for the following operating frequencies.

4. CONCLUSION

A novel three-branch-strip monopole antenna for WLAN/WiMAX application was constructed and successfully implemented. The designed antenna consists of three strips, an asymmetrical ground plane, and a rectangular slit in the ground, and was designed for dual-band WLAN/WiMAX application. The three-strip design showed good impedance bandwidth matching of less than 1:2 VSWR and achieved over the WLAN/WiMAX bands. It can generate three resonance values centered at about 2.4, 3.7, and 5.5 GHz to cover the 2.4/5.2/5.8GHz WLAN bands and the 3.5/5.5GHz WiMAX bands. Various parameters of the proposed antenna were optimized through a simulation, and the optimized geometry was prototyped. A prototype that was capable of generating two wide resonant modes to cover WLAN/WiMAX systems was tested. This proposed antenna had an impedance bandwidth (VSWR, 1:2) of about 245 MHz and 3,945 MHz (2,340-2,585 MHz and 3,215-7,160 MHz, respectively), or about 9.95% and 76.05%, respectively. The proposed antenna has nearly omni-directional radiation characteristics and a moderate gain over the operating bands. Also, the measured peak gain of the proposed antenna varied from -0.557 to 5.952 dBi.

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