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Research Article

Bandwidth Enhancement Technique of the Meandered Monopole Antenna

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A small dual-band monopole antenna with coplanar waveguide (CPW) feeding structure is presented in this paper. The antenna is composed of a meandered monopole, an extended conductor tail, and an asymmetrical ground plane. Tuning geometrical structure of the ground plane excites an additional resonant frequency band and thus enhances the impedance bandwidth of the meandered monopole antenna. Unlike the conventional monopole antenna, the new resonant mode is excited by a slot trace of the CPW transmission line. The radiation performance of the slot mode is as similar as that of the monopole. The parametrical effect of the size of the one-side ground plane on impedance matching condition has been derived by the simulation. The measured impedance bandwidths, which are defined by the reflection coefficient of −6 dB, are 186 MHz (863–1049 MHz, 19.4%) at the lower resonant band and 1320 MHz (1490–2810 MHz, 61.3%) at the upper band. From the results of the reflection coefficients of the proposed monopole antenna, the operated bandwidths of the commercial wireless communication systems, such as GSM 900, DCS, IMT-2000, UMTS, WLAN, LTE 2300, and LTE 2500, are covered for uses.

1. Introduction

Because of the recent demand to incorporate more communication services, multiband antennas that are designed with sufficient bandwidths to cover operating bands are presently very important topics of research. Among these antennas, the monopole antenna, especially the CPW feeding structure, has received much attention owing to its attractive advantages such as low profile, light weight, broad impedance bandwidth, and easy fabrication [1–6]. A compact rectangular meandered monopole, which has a dual-frequency bandwidth operation, is proposed to work at GSM 900 and DCS 1800 systems [1]. The utilization of the meandered topology results in the reduction of the operated frequencies, including the fundamental band and harmonics. However, due to a high quality factor resulting from the meandered topology, the impedance bandwidth is quite narrow. A novel single-layer planar monopole for dual-band operation is shown in [3]. The effect of the impedance matching condition on size variation of the ground plane has been extensively investigated. In [5], a dual-band CPW-fed monopole antenna with an asymmetrical ground plane structure is presented. By tuning the width of the CPW ground plane, it is found that the impedance bandwidth with dual-band operation is achieved. A triple-band antenna with a LI-shaped radiating topology and coplanar waveguide (CPW) feeding is presented in [6]. Both resonance numbers and impedance bandwidths are easily improved by utilizing the monopole structure.

In this study, a dual-band meandered monopole antenna with the CPW feeding structure is fabricated and shown. The use of the meander-shaped topology reduces the operated frequency so that the antenna dimension can be miniaturized. By tuning the geometrical parameters of one side of the CPW ground plane, an additional resonance appears. An extended conductor tail is added at the end of the meandered monopole antenna so that the lower resonant band around 900 MHz is excited. Furthermore, the harmonics of the meandered monopole antenna also shifts down. The antenna's performance is simulated using commercial simulation software prior to its fabrication. Details of

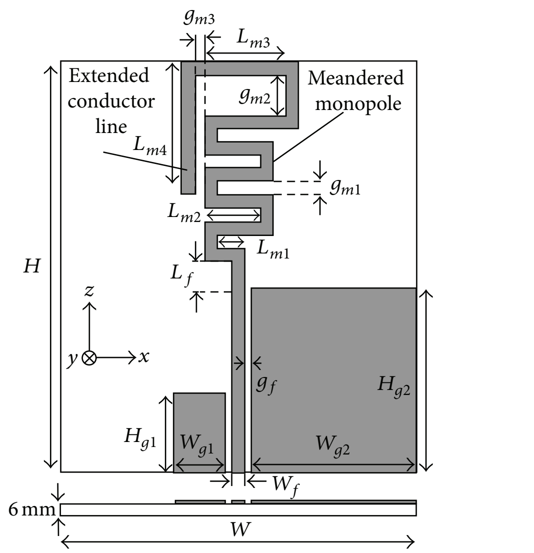


FIGURE 1: Geometry of the proposed antenna with asymmetrical ground plane.

TABLE 1: Geometric parameters of proposed antenna.

Parameter	W_{g1}	H_{g2}	L_{m3}	g_{m2}
Unit: mm	9.5	30	13	6
Parameter	W_{g2}	L_f	L_{m4}	g_{m3}
Unit: mm	27.5	7	20	1.5
Parameter	W_f	L_{m1}	g_{m1}	g_f
Unit: mm	2	4.5	2	0.2
Parameter	H_{g1}	L_{m2}	H	W
Unit: mm	13	9	67	38

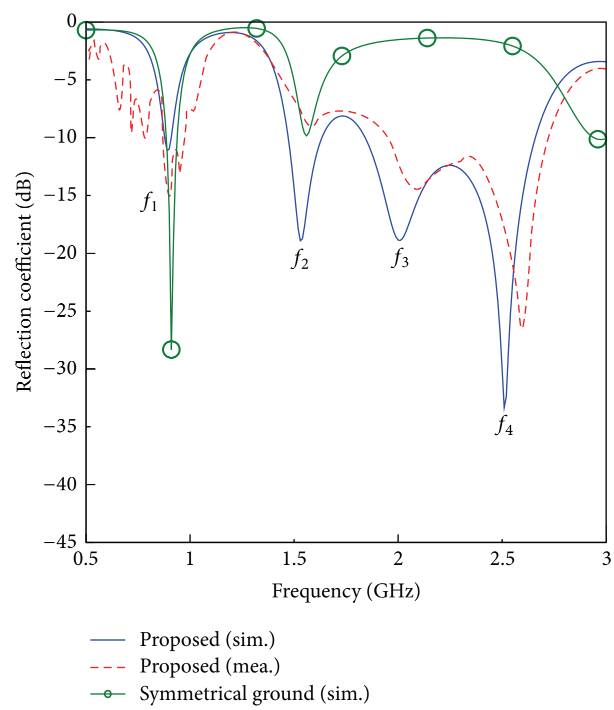


FIGURE 2: Simulated and measured reflection coefficients of the proposed antenna.

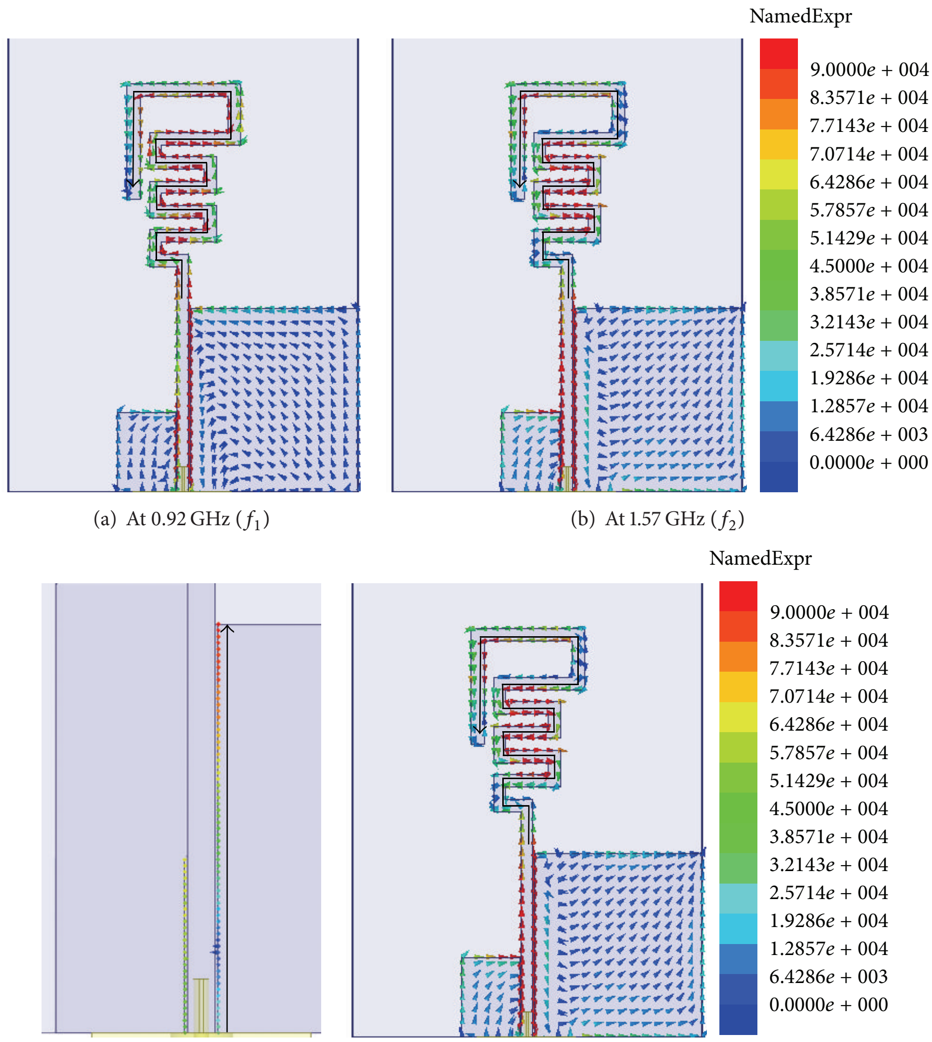
the antenna design are studied, and the proposed antenna is experimentally examined to demonstrate the antenna performance. The radiation mechanism of the proposed antenna is also explained by the distribution of the electric and magnetic current distributions.

2. Antenna Design

The schematic diagram of the proposed CPW-fed meandered monopole antenna is shown in Figure 1. The proposed antenna is composed of a meandered monopole, an extended conductor tail, and a CPW feeding structure with the asymmetrical ground plane. The geometric parameters of the antenna are listed in Table 1. This antenna is fabricated on one side of the FR4 substrate with a dielectric constant ε_r of 4.4, thickness of 1.6 mm, and no metallization on the other side. The width and gap of the CPW feed line are determined to be 2 mm and 0.2 mm, which corresponds to the characteristic impedance of 50 Ω. The meandered monopole, which is a basis of the antenna structure, has the dimensions of 15 mm in width and 37 mm in height. A conductor tail of length 20 mm is connected to the end of the meandered monopole. This conductor tail is adjacent to the meandered monopole, where the space between the tail and meandered trace is 1.5 mm. In order to improve the impedance matching condition, the width of the top segment of the meandered trace is varied. Very different from a conventional structure, the CPW structure of the proposed antenna has two asymmetrical ground plane segments. As depicted in Figure 1, the arrangement of different size of the ground planes results in a new current path and thus excites a new resonant mode. These techniques enhance the impedance bandwidth of the meandered monopole antenna. The simulation and measurement results are given in the next section.

3. Results and Discussion

In our experiment, the design and simulation of the proposed CPW-fed monopole antenna were conducted by using the EM software ANSYS High Frequency Structure Simulator (HFSS). With the assistance of this commercial software, the expected characteristics of the antenna can be fully achieved. A comparison of the simulated and measured reflection coefficients of the proposed meandered monopole antenna is shown in Figure 2. In order to clarify the difference, the simulated reflection coefficient of the conventional meandered monopole with the symmetrical ground plane is also added into the figure. In the following discussion, the impedance bandwidth is defined by the reflection coefficient smaller than −6 dB, which is enough to receive and transmit the signal power for commercial wireless communication systems. For the conventional antenna with the symmetrical ground plane, there are three resonant frequencies, radiated by the fundamental mode and first harmonic and second harmonic of



(a) At 0.92 GHz (f_1)

(b) At 1.57 GHz (f_2)

(c) At 2.02 GHz (f_3)

(d) At 2.51 GHz (f_4)

Figure 3: Simulated current distribution of the proposed antenna. (a), (b), and (d) electric current. (c) magnetic current.

the meandered monopole trace. Their corresponding resonant lengths are 1/4, 3/4, and 5/4 wavelengths long. The operated frequency bands are at 0.93, 1.62, and 2.98 GHz. From the results of this figure, the measured impedance bandwidths of the proposed antenna are 186 MHz (0.863 to 1.049 GHz, 19.4%) and 1320 MHz (1.490~2.810 GHz, 61.3%) corresponding to the simulated impedance bandwidths which are 94 MHz (0.848 to 0.942 GHz, 10.5%) and 1317 MHz (1.432~2.749 GHz, 62.9%). The discrepancies between the simulated and measured results might be attributed to fabrication tolerances and material parameter uncertainty. To compare with the frequency-characteristics performance of the conventional monopole antenna, it is seen that enhancement of the impedance-matching condition and bandwidth is achieved. The simulated result shows that four resonant frequencies of the proposed meandered monopole antenna are excited at 0.92, 1.57, 2.02, and 2.51 GHz, and merging of three upper resonant frequencies causes the broadband operation. A new resonant band around 2.02 GHz is excited and the resonance frequencies of the harmonic modes decrease. The design of utilizing an asymmetrical ground plane does not only increase the resonances but also significantly improve the impedance bandwidth at the high frequency band. The reason will be explained by the surface electric current distribution.

Figure 3 presents the simulated surface current distributions of the proposed meandered monopole antenna for the four resonant modes. In Figure 3(a), the simulation result shows that the first resonant mode (f_1) of the proposed antenna is mainly dominated by a quarter-wavelength path along the meandered monopole with the extended conductor tail. In Figure 3(b), owing to a current null on the meandered trace, it is determined that this resonant mode (f_2) is the first harmonic of the meandered monopole. Observing the distribution of the equivalent magnetic current in Figure 3(c), it is seen that the third resonant mode (f_3) is excited by the right-side slot of the CPW transmission line. Compared to the symmetrical-ground plane topology with cancellation of the opposite slot current components, the antenna with

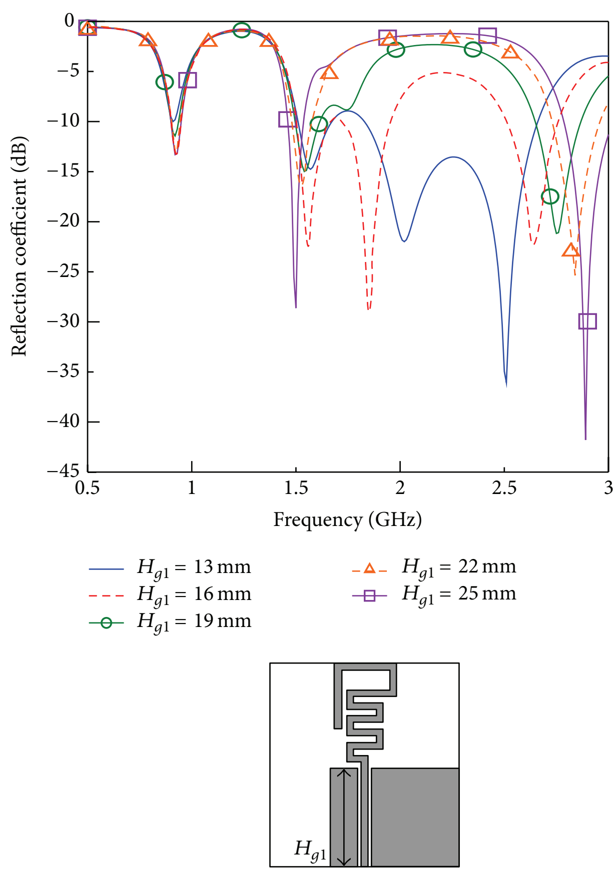


Figure 4: Comparison of simulated reflection coefficients of the proposed antenna with various H_{g1}.

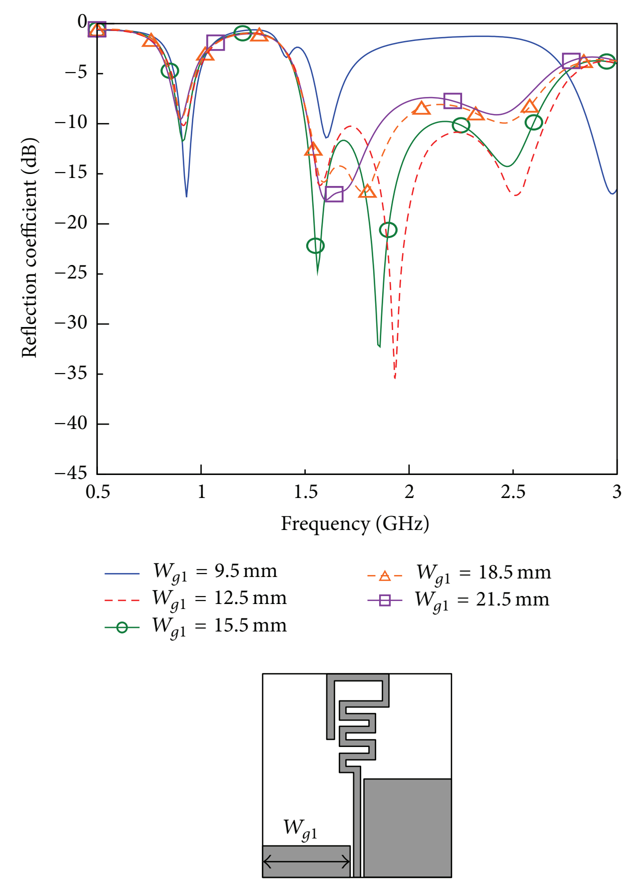
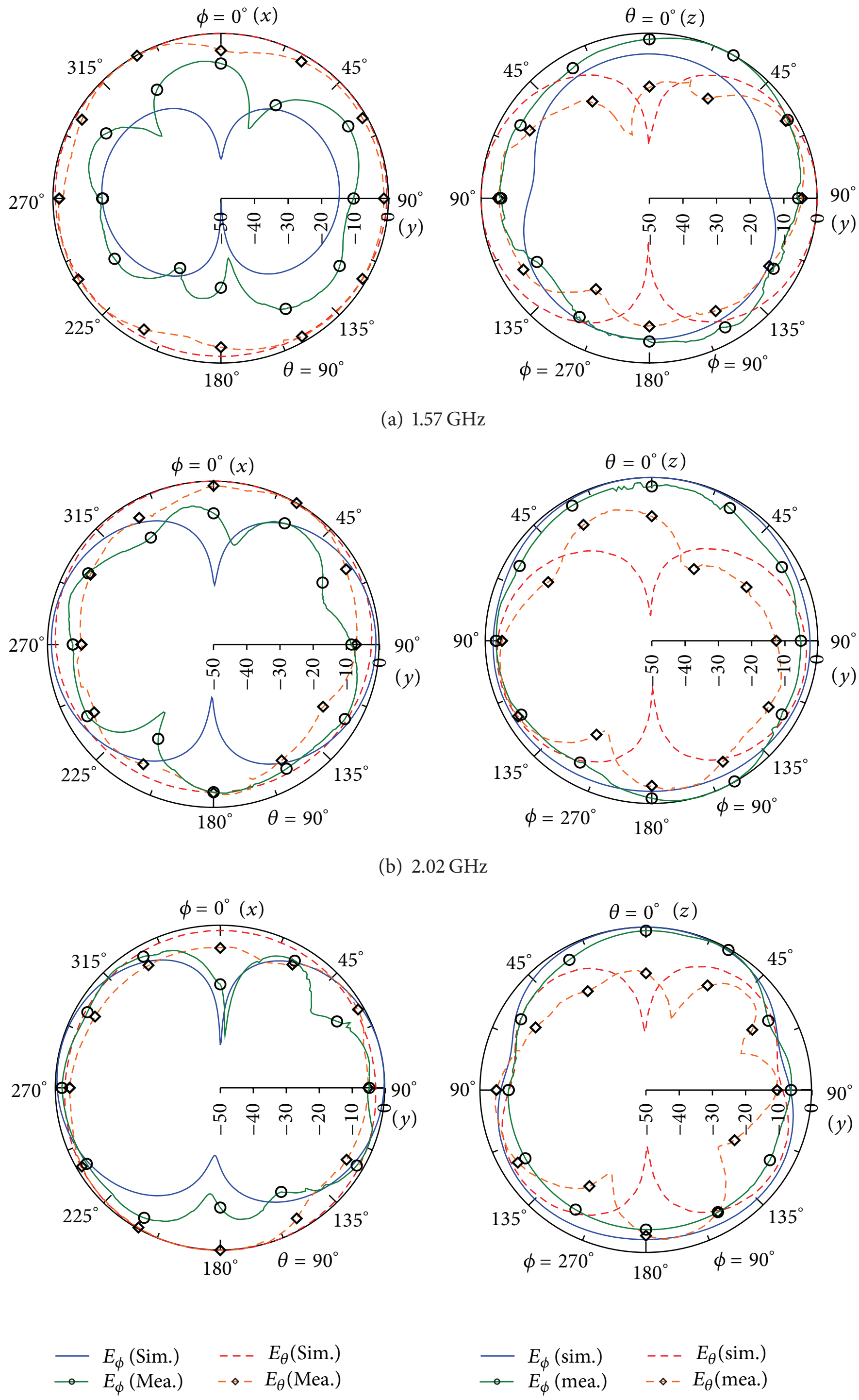


Figure 5: Comparison of simulated reflection coefficients of the proposed antenna with various W_{g1}.

the asymmetrical ground plane can excite one quarter-wave slot mode, which is not cancelled by the other slot component. The distribution of the surface electric current in Figure 3(d) shows that the forth resonant frequency (f_4) is the second harmonic of first resonant mode (f_1). Two current nulls are observed along the meandered path.

A parametric study of the proposed monopole antenna is accomplished for understanding the mechanism of the asymmetric ground plane. The geometrical dimensions of the left side of the ground plane are varied in order to analyze the frequency characteristics of the proposed antenna. Figure 4 shows the dependence of the reflection coefficients on the height (H_{g1}) of the left ground patch varied from 13 to 25 mm. It can be found that when the height increases, the lower three resonances shift down, and the fourth resonance moves up. The reason of frequency reduction may be attributed to increase of the capacitance caused by the separation between the left ground patch and the feed line. On the contrary, the resonant path at the fourth resonance shortens, thus giving frequency increase. Figure 5 exhibits the effects of adjusting the width (W_{g1}) of the left ground patch on the frequency characteristics. The operated frequency of the third resonance mode shifts down because of the enhancement of the inner capacitance, resulting from increase of the ground width. However, the impedance matching condition of the proposed antenna is deteriorated so that the impedance bandwidth decreases.

Due to the limit of the measurement system for our chamber below 1 GHz, the radiation patterns of the proposed antenna at 900 MHz will be not presented. The other radiation patterns above 1 GHz will be shown in simulation and measurement. Figure 6 is the comparison of the radiation patterns of the proposed meandered monopole antenna in the xz and yz planes. Although the excitation at 1.57 GHz and 2.51 GHz (see Figures 6(a) and 6(c)) is the higher order mode, the E_ϕ and E_θ radiation patterns in the xz and yz planes are similar to those of the fundamental mode. The horizontal components of the current are mutually cancelled owing to the meandered topology, where only the vertical components exist. Figure 6(b) is the comparison of simulated and measured radiation patterns of the proposed antenna at 2.02 GHz. In Figure 3(c), it is known that the power radiation is dominated by the magnetic current inside the slot between the feed line and the right part of the ground plane. Since the direction of the magnetic current is the same as the electric current of the monopole trace, the radiation patterns of the slot mode are as similar as those of the monopole mode, shown in Figures 6(a) and 6(c).



(a) 1.57 GHz

(b) 2.02 GHz

(c) 2.51 GHz

Figure 6: Comparison of the simulated and measured radiation patterns of the proposed antenna in the xz and yz planes at (a) 1.57 GHz, (b) 2.02 GHz, and (c) 2.51 GHz.

4. Conclusion

In this paper, we successfully demonstrate a compact meandered monopole antenna with coplanar-waveguide feeding structure. By eliminating the geometric dimension of one side of the ground plane, a wide impedance bandwidth with dual-band operation is provided. To compare with the conventional meandered monopole antenna, one additional resonance band by a slot path is excited and observed. This proposed antenna may be a candidate for an RX/TX element of the commercial wireless communication systems, such as GSM 900 (at 0.9 GHz), DCS (at 1.8 GHz), PSC (at 1.9 GHz), IMT-2000 (at 2.1 GHz), WLAN (at 2.4 GHz), and LTE (at 2.3 GHz and 2.6 GHz).

Conflict of Interests

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

Acknowledgments

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