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COPLANAR PRINTED MONOPOLE ANTENNA USING COAXIAL FEEDLINE FOR DTV APPLICATION

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Abstract—This article presents a coplanar printed monopole antenna for digital television (DTV) in the UHF band (470–862 MHz) application. The antenna structure consists of a meander loop monopole for radiation, a step-shaped ground plane for impedance matching, and a 50-Ω mini coaxial feedline for excitation. The meander loop monopole and step-shaped ground plane are printed on the same side of a substrate with an area of $15 \times 170\,\text{mm}^2$. The measured impedance bandwidth for 2.5 : 1 voltage standing wave ratio (VSWR) is 550 MHz (465–1015 MHz, 74%), covering the DTV band. In addition, the proposed antenna shows a real reception performance on a notebook computer. The reception results for audio and video signals exhibit stable characteristics.

1. INTRODUCTION

In recent years, the DTV reception has been extensively developed in many countries. The main reasons include high resolution video, high internet compatibility, and easy integrated into mobile device. Currently, some popular planar antenna designs for application in the DTV band have been reported in the literatures [1–7], such as modified H-shaped antenna [1], broadband printed dipole antenna [2, 3], wideband monopole antenna with a concave or short-circuit sleeve ground plane [4, 5], folded metal plate monopole with L-shape slit [6], and combining a meaner line inverted-L shape and loop antenna [7]. For comparison, the antenna area and operation bandwidth of the above-mentioned planar antennas are summarized in Table 1. This table indicates that a monopole antenna with short-circuit sleeve [5] has a maximum operation bandwidth of 560 MHz as compared with other antennas but also possesses a large size of $50 \times 229\,\text{mm}^2$.

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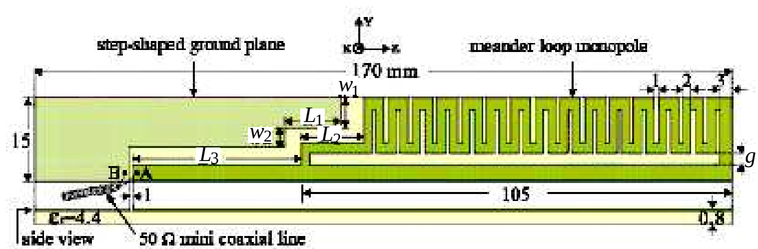
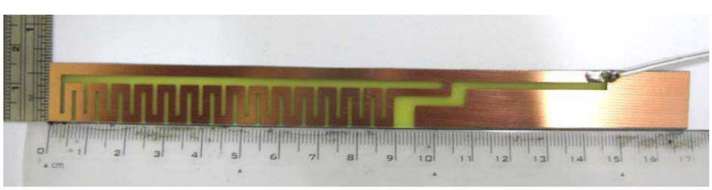
The purpose of this study is to design a new printed monopole antenna that not only preserves a large operation bandwidth but also reduces antenna size that is comparable to those of planar antennas in Table 1. This article proposes a new coplanar meander loop monopole antenna with a step-shaped ground plane, which has an area of $15 \times 170\,\text{mm}^2$ and bandwidth of 550 MHz (2.5 : 1 VSWR) for DTV application. The simulated and measured results show that the proposed antenna can achieve sufficient impedance bandwidth and exhibit typical monopole antenna radiation characteristics.

Table 1. The area and operation bandwidth of some planar antennas [1–7] for DTV band.

Ref.	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Ant. area (mm×mm)	60×257	20×227	14×230	35×247	50×229	70×195	75×135
VSWR	3 : 1	2.5 : 1	3 : 1	1.92 : 1	2.5 : 1	1.92 : 1	3.5 : 1
Operation bandwidth (MHz)	240 (470–710), 41%	340 (470–810), 53%	490 (470–960), 69%	461 (451–912), 68%	560 (470–1030), 75%	280 (465–745), 46%	400 (470–870), 60%



(a)



(b)

Figure 1. Proposed coplanar printed monopole antenna. (a) Antenna configuration and (b) fabricated antenna photograph.

2. ANTENNA DESIGN

2.1. Antenna Configuration

Figures 1(a)–(b) show the configuration of the meander loop monopole antenna with a step-shaped ground plane. The proposed antenna with an area of $15 \times 170\,\mathrm{mm}^2$ is constructed on a low cost FR4 substrate with thickness of 0.8 mm and relative permittivity of 4.4. The radiating element consists of a meander structure and straight strip line with a width of 3 mm and length of 146 mm ($L_3 + 105\,\mathrm{mm}$). The meander structure is composed of an inverted L-shaped strip line with a width of 2 mm and length of L_1, a meander line with the equal vertical and horizontal widths of 2 mm and uniform spacing of 1 mm. The meander structure connects in parallel with the straight strip line to form a meander loop monopole. The geometrical parameter g denotes the gap between the meander structure and the straight strip line. This is an important parameter for fine-tuning impedance matching. The step-shaped ground plane (the dimensions of w_1, w_2, and L_1) is designed to control the impedance bandwidth for the upper band. The meander loop monopole and the step-shaped ground plane are printed on the same side of the substrate. A 50-Ω mini coaxial line is used to feed the antenna by point A and B, as shown in Figure 1(a).

Actually, the proposed antenna used a meander structure to reduce size of the antenna for the lower band operation. To excite another resonant mode in the upper band for broadband operation, we used a straight strip line to connect in parallel with the meander structure to form a meander loop monopole. However, only the meander loop monopole structure is difficult to realize good impedance matching. Therefore, designing the step-shaped ground plane achieves broadband matching.

2.2. Parametric Study

To understand the effects of the key parameters for the meander loop monopole, Figures 2(a)–(c) show the measured results for the return loss by varying geometric parameters of g, L_2, and L_3, respectively. When the gap of g increases from 0.5 to 2.5 mm in Figure 2(a), the impedance bandwidth obviously changes because the coupling effect between the meander structure and the straight strip line is varied. Figure 2(b) shows the measured return loss for the meander structure with varying the length of L_2. It is found that the impedance bandwidth can be improved for the upper band. Similarly, the measured result with varying L_3 is shown in Figure 2(c). Note that the operating frequencies obviously vary in the lower and upper

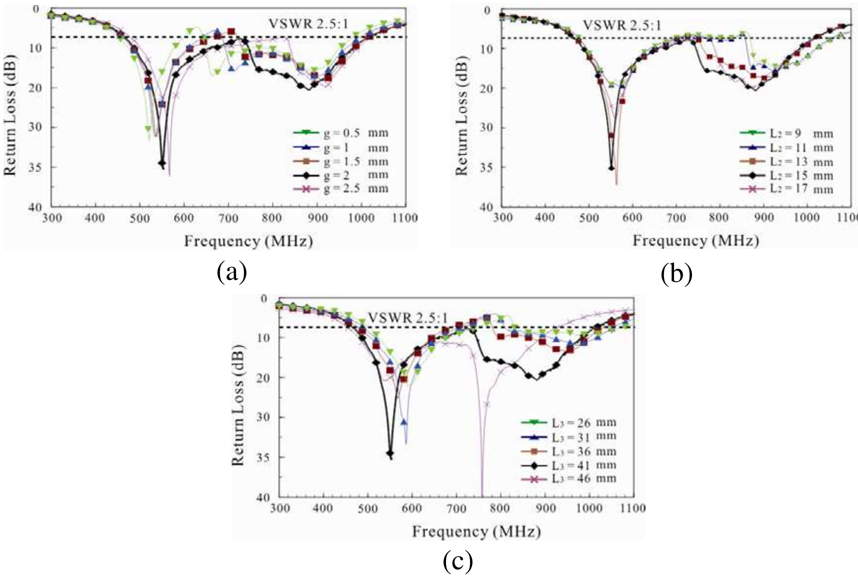


Figure 2. Measured return loss for the meander loop monopole with various geometric parameters (a) g, (b) L_2 and (c) L_3.

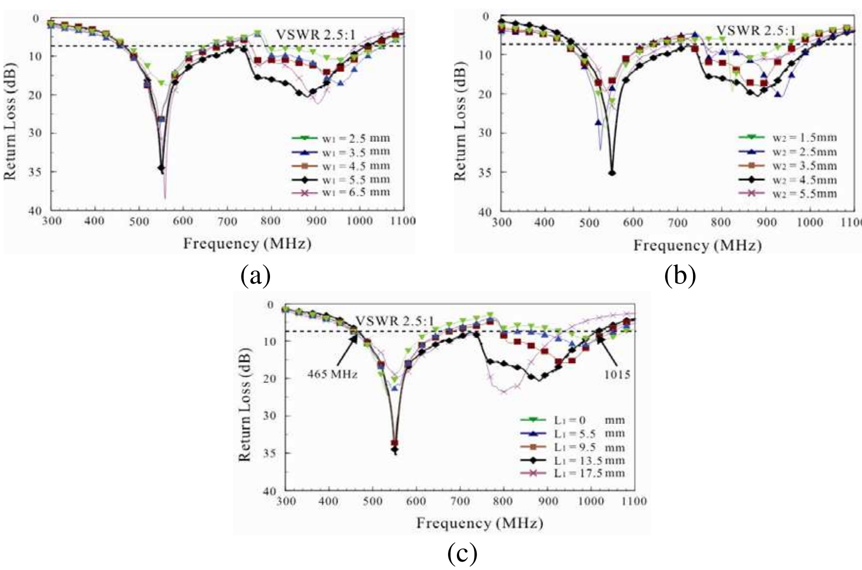


Figure 3. Measured return loss for the step-shaped ground plane with geometric parameters (a) w_1, (b) w_2 and (c) L_1.

bands because the length of L_3 is the beginning current path of the meander loop monopole so as to affect the operating frequencies more significantly.

Figures 3(a)–(c) show the effects of the step-shaped ground plane with geometric parameters of w_1, w_2, and L_1 on the performance of the meander loop monopole antenna. These measured results indicate that the impedance bandwidth exhibits obvious variation especially in the upper band. Due to the coupling effect between the step-shaped ground plane and the meander loop monopole, a mutual coupling is enhanced so as to improve the impedance bandwidth in the upper band more significantly. Noted that the length of $L_1 = 0$ (forming into a rectangular ground plane) produces a worse impedance matching especially in the upper band, as shown in Figure 3(c).

2.3. Current Distribution

The excited surface current distributions of the proposed antenna were obtained by using Ansoft HFSS simulation software. Figures 4(a) and 4(b) show the excited surface current distributions for the meander loop monopole with the step-shaped ground plane at 550 and 880 MHz, respectively. As predicted, the proposed antenna has a large surface current density along the meander structure for operating frequency at 550 MHz. It is noted that the coupling effect between meander lines with opposite current vectors cause a significant reduction in the effective length of the meander structure [7, 8]. For an operating frequency of 880 MHz, the surface current density is enhanced for the beginning path of the straight strip line. This is because the path length ($L_3 = 41$ mm) is close to a quarter-wavelength at 880 MHz.

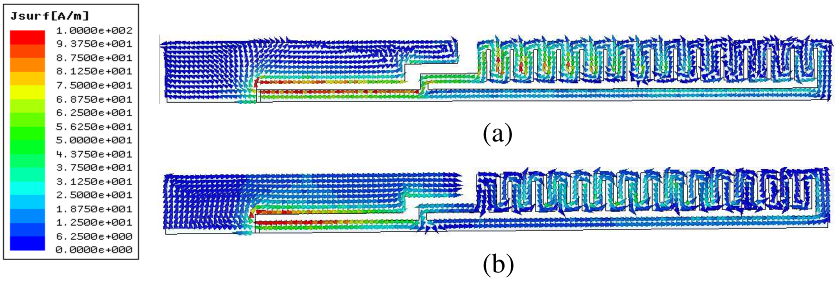


Figure 4. Simulated results of surface current density for the proposed antenna at (a) 550 MHz and (b) 880 MHz.

Table 2. The optimum dimensions of the proposed antenna and measured impedance bandwidth for 7.5-dB return loss (2.5 : 1 VSWR).

L_1 (mm)	L_2 (mm)	L_3 (mm)	w_1 (mm)	w_2 (mm)	g (mm)	Bandwidth (MHz, %)
13.5	15	41	5.5	4.5	2	550 (465–1015), 74

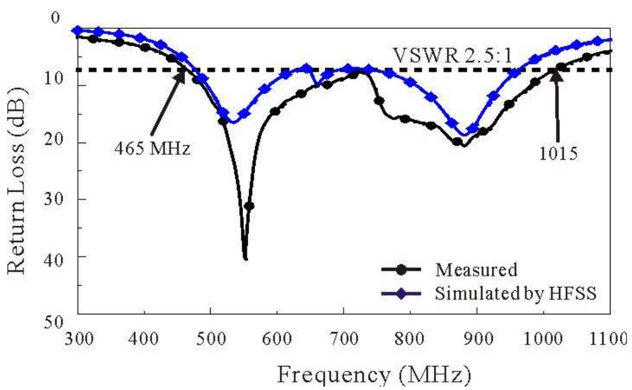


Figure 5. Measured and simulated return loss for the proposed antenna.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 5 shows good agreement between the simulated and measured results for the return loss of the proposed antenna. The impedance bandwidth for 7.5-dB return loss (2.5 : 1 VSWR) reaches 550 MHz (465–1015 MHz), and corresponds to a fractional bandwidth of 74% for central frequency at 740 MHz. Table 2 summarizes the proposed antenna optimum dimensions, measured impedance bandwidth and operating frequency range. Compared with the literatures reported in [1–7], the proposed antenna offers a sufficient fractional bandwidth of 74% and has a compact area of $15 \times 170\,\text{mm}^2$. The results show that this antenna is suitable for DTV application.

For the radiation characteristics, only the simulated results by using the HFSS software are exhibited because our anechoic chamber is unable to operate at lower frequencies such as in the DTV band. Figures 6(a)–(c) show the simulated radiation patterns for operating frequency at 550, 780, and 880 MHz, respectively. From an overall view of these radiation patterns, the antenna behaves quite similar

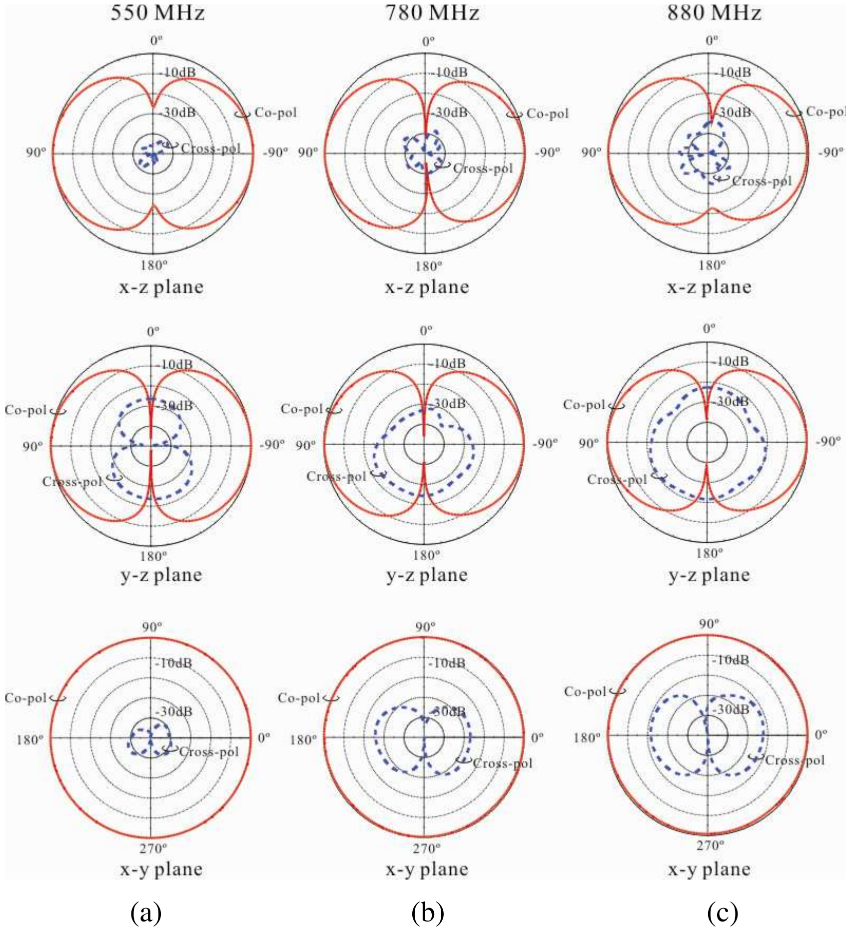


Figure 6. Simulated radiation patterns for the proposed antenna at (a) 550, (b) 780 and (c) 880 MHz.

to a typical monopole antenna. The H-plane (x-y plane) patterns are almost omnidirectional radiation at 550, 780, and 880 MHz. The simulated antenna gain for the operating band (465–1015 MHz) varies from 0.2 to 1.1 dBi, and the average gain is about 0.5 dBi. To confirm real performance of the proposed antenna, a simple reception system is shown in Figure 7. This system consists of the proposed antenna, a digital TV stick (DTV tuner) [9] and a notebook computer. The proposed antenna connects the DTV stick, which inserts to the USB port of the notebook computer. Reception results in Figure 7 exhibit a stable picture and clear audio.

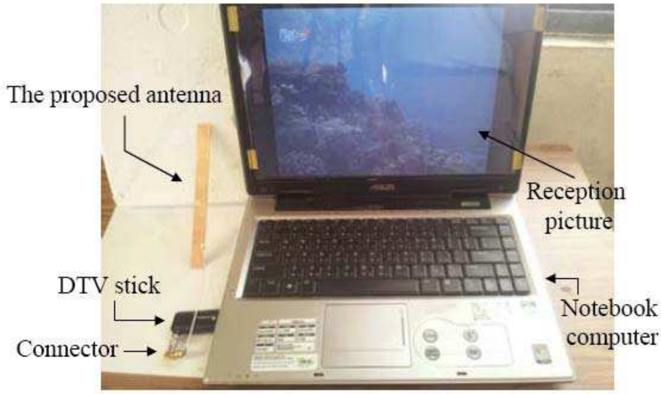


Figure 7. Real reception performance for the proposed antenna on a notebook computer.

4. CONCLUSION

A new meander loop monopole antenna with a step-shaped ground plane for DTV broadband operation has been presented. The meander loop monopole can excite two resonate modes. The step-shaped ground plane can improve impedance matching to achieve bandwidth of 550 MHz (465–1015 MHz, 74%) for 2.5 : 1 VSWR. The simulated, measured and real reception results demonstrate that the proposed antenna can be successfully used in DTV operation.

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