Planar DVB-T Antenna Using a Patterned Helical Line and Matching Circuit

Jong-Hyuk Lim and Tae-Yeoul Yun

A miniaturized planar digital video broadcasting terrestrial (DVB-T) antenna, which is composed of a patterned helical line, an open stub, and an impedance matching circuit on an FR4 (ε_r=4.4) substrate for portable media player applications, is presented in this letter. The antenna has monopole-like, omni-directional radiation characteristics and a wide impedance bandwidth (VSWR<3) in the DVB-T band from 174 MHz to 230 MHz at the VHF band.

Keywords: DVB-T, helical line, internal antenna, wide bandwidth.

I. Introduction

Due to the rapid progress in digital mobile TV broadcasting service, a digital video broadcasting terrestrial (DVB-T) system that can provide TV broadcasting service outdoors through handheld devices, such as mobile phones, portable digital assistants (PDAs), portable media players (PMPs), and notebooks, has recently become popular. The operating frequency bands of the DVB-T system are very wide, ranging from 174 MHz to 230 MHz (56 MHz, 27.72%) at the VHF band, which has about a 1.5 m wavelength at the center frequency (200 MHz). Therefore, a miniaturized antenna is required; however, this results in a narrow bandwidth due to the reduction in the effective size [1]. Thus, an optimum antenna design with a compact size and broad bandwidth has yet to be identified.

Recently, various methods have been proposed to solve this problem [1]-[4]. A wideband active small antenna using a dummy antenna was developed for the terrestrial digital multimedia broadcasting (T-DMB) service operating on frequency bands from 174 MHz to 216 MHz, which was adopted for various mobile electronics in South Korea [1]. The performance of that antenna revealed that a low noise amplifier plays an important role in achieving wideband characteristics. In [2], a compact dipole antenna for the T-DMB band was presented using a commercial wideband balun to divide the feed RF signal into two 50 Ω signal lines. However, this technique increases the antenna cost. In addition, frequency tunable antennas for T-DMB were presented in [3] and [4]. These antennas can be easily tuned over the wideband by controlling the switch. However, the system complexity increases with the transistors and varactors used.

In this letter, we propose a broadband internal antenna using a patterned helical line, an open stub, and a lumped-elements matching circuit in a real PMP platform (i-station U43, Digital-Cube) [5]. The patterned helical line antenna and the open stub are based on a monopole antenna and are printed on an FR4 substrate. The patterned antenna size is used to generate a quarter wavelength of a monopole antenna. The proposed antenna is easily fabricated due to the planar configuration.

II. Antenna Design

Figure 1 shows the geometry of the proposed internal DVB-T antenna in a PMP mock-up case. It consists of a patterned helical line (width=0.3 mm) on both sides of a substrate connected by via holes (radius=0.3 mm), an open stub, and an input impedance matching circuit on an FR4 substrate with a relative permittivity (ε_r) of 4.4 and a thickness of 1 mm in a commercial PMP mock-up case, which has a relative

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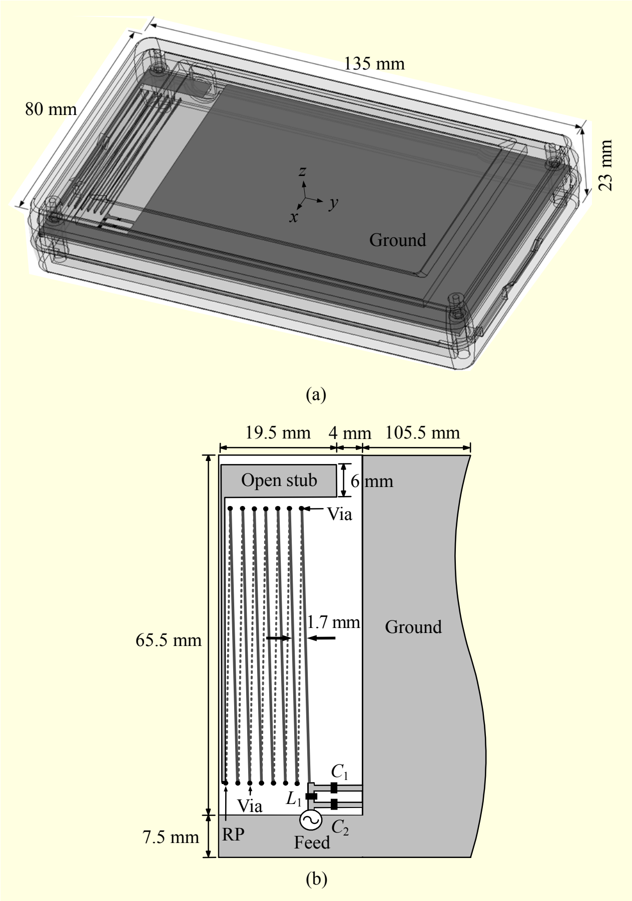

Fig. 1. Proposed DVB-T antenna: (a) 3D perspective view in PMP mock-up case and (b) geometry of antenna.

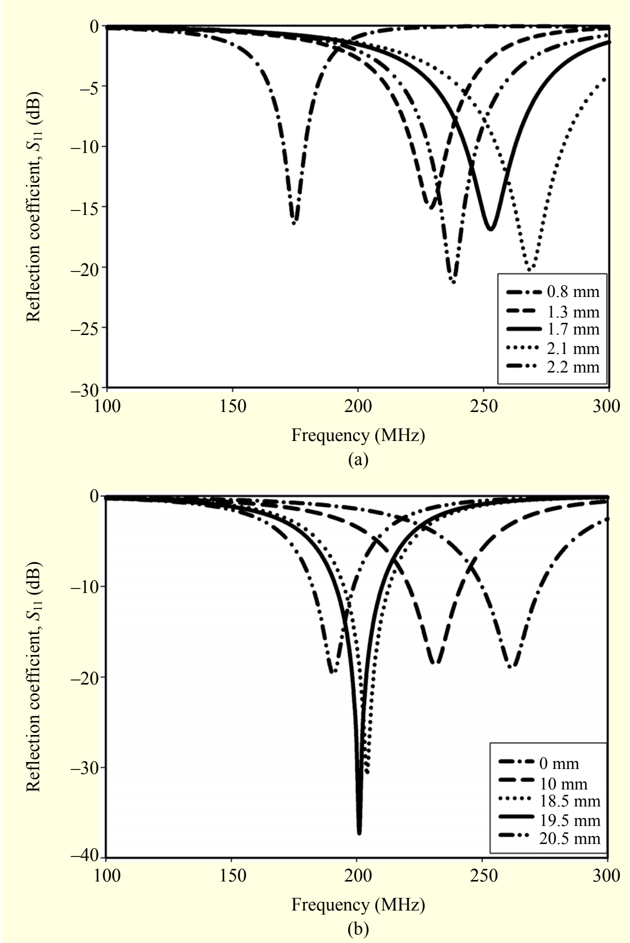

Fig. 2. Parametric analysis of radiating elements varying: (a) pitch of helical line and (b) open stub.

permittivity (ε_r) of 3.2 and a total volume of 135 mm×80 mm ×23 mm. The detailed dimensions of the proposed planar and internal antenna are illustrated in Fig. 1(b). The system size is 129.5 mm×73 mm with a pure antenna size of 65.5 mm× 24 mm on the FR4 substrate. The proposed antenna is fed by a coaxial probe through the matching circuit. Two capacitors (C_1 and C_2) and one inductor (L_1) are used to achieve the broad input impedance matching.

The proposed antenna with the patterned helical line and the open stub has a printed monopole antenna structure that resonates at one-quarter wavelength of the frequency. The patterned helical line antenna for a low profile and a broad bandwidth is used to generate a low resonant frequency of the DVB-T band (f_c=200 MHz). To design and optimize the helical-type antenna for a broad bandwidth, many parameters were considered, such as the pitch, turn, line-width, and so on. The pitch of the helical structure plays a particularly important role in the antenna bandwidth and size. In addition, an open stub expanding an additional length from the end of the helical line was investigated to decrease the resonant frequency of the helical antenna. Ansoft's high frequency structure simulator (HFSS) was used to simulate and optimize the proposed antenna in this study.

To demonstrate the effects of the pitch of the helical line and the length of the open stub, the parametric analysis of the proposed antenna was performed, as shown in Fig. 2. In all of the analyses, the helical line was fixed at seven turns. The pitch was varied from 0.8 mm to 2.2 mm at a fixed reference point (RP), and the simulated operating frequencies of the input reflection coefficient (S_{11}) shifted upward and broadened to a pitch of 2.1 mm because the self-capacitive coupling of the helical line decreased as shown in Fig. 2(a). When the pitch was longer than 2.1 mm, the operating frequency shifted downward because the capacitive coupling between the helical line and the ground plane increased. The length of the open stub varied from 0 to 20.5 mm, while the helical line was fixed at seven turns and 1.7 mm of pitch. As the length of the open stub increased, S_{11} moved downward but the bandwidth hardly changed, as shown in Fig. 2(b). As a result, the determined and open stub length were 1.7 mm and 19.5 mm, respectively, and thus the impedance bandwidth of –6 dB was 30 MHz over 184 MHz, at 214 MHz. However, the structure still did not satisfy the whole impedance bandwidth of the DVB-T band, so we added a π-matching network like a lowpass filter, which consists of two capacitors and one inductor and widens the impedance bandwidth. To optimize the values of the lumped components for bandwidth enhancement, we simulated the impedance matching characteristics on the Smith chart step-by-step. First, when only the parallel C_1 was used, the trace on the Smith chart plot rotated clockwise along the 3:1 VSWR circle, as shown in Fig. 3(a). Next, when the series L_1 was added, the trace was rotated further in a clockwise direction. Finally, the parallel C_2 made the trace plotted in the 3:1 VSWR circle, as shown in Fig. 3(b). As a result, the lumped component values obtained were C_1=18 pF, L_1=47 nH, and C_2=28 pF to expand the bandwidth over 173 MHz to 231 MHz.

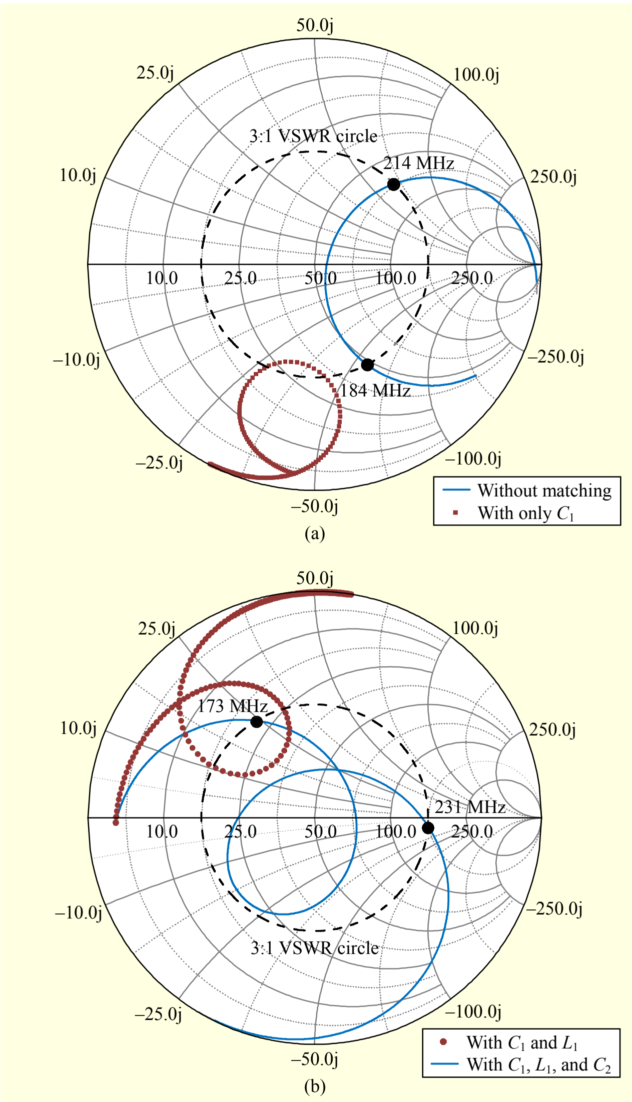

Fig. 3. Simulated S_{11} when each matching element is added: (a) C_1 and (b) C_1, L_1, and C_2.

III. Experiment Results and Discussion

To investigate the performance of the proposed internal DVB-T antenna, the antenna was fabricated and measured in the PMP mock-up case as shown in Fig. 4. An HP8510C vector network analyzer was used to measure the reflection coefficient (S_{11}) of the fabricated antenna.

Figure 5 shows the simulated and measured S_{11} of the proposed antenna with and without the input matching circuit. With the matching circuit, the simulated and measured impedance bandwidth was approximately 56 MHz (174 MHz to 230 MHz, 27.72%), which is sufficient bandwidth to cover the whole DVB-T band well. As a result, the impedance bandwidth with the matching circuit was broadened by about 50% compared to the antenna without the matching circuit. The simulated and measured results were very consistent.

Figures 6(a), 6(b), and 6(c) display the measured *E*- and *H*-plane radiation patterns of the fabricated antenna embedded in

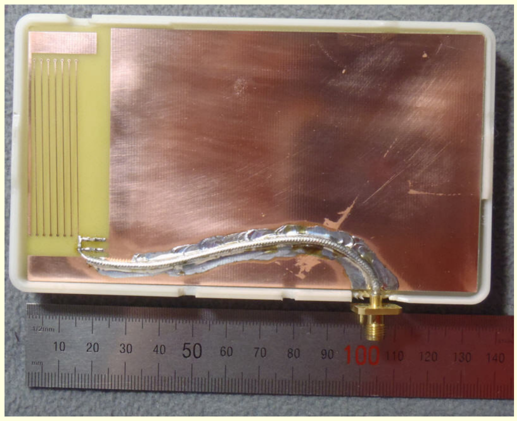

Fig. 4. Photograph of fabricated antenna in PMP mock-up case.

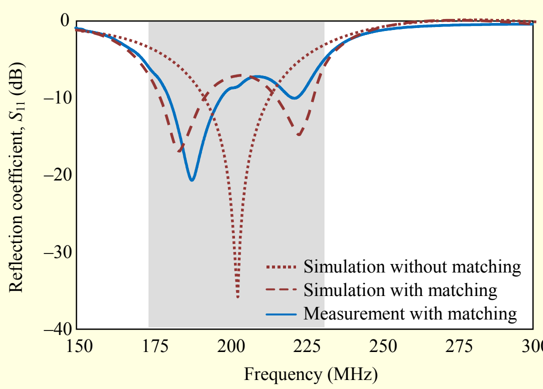

Fig. 5. Simulated and measured S_{11} of proposed DVB-T antenna with and without matching circuit.

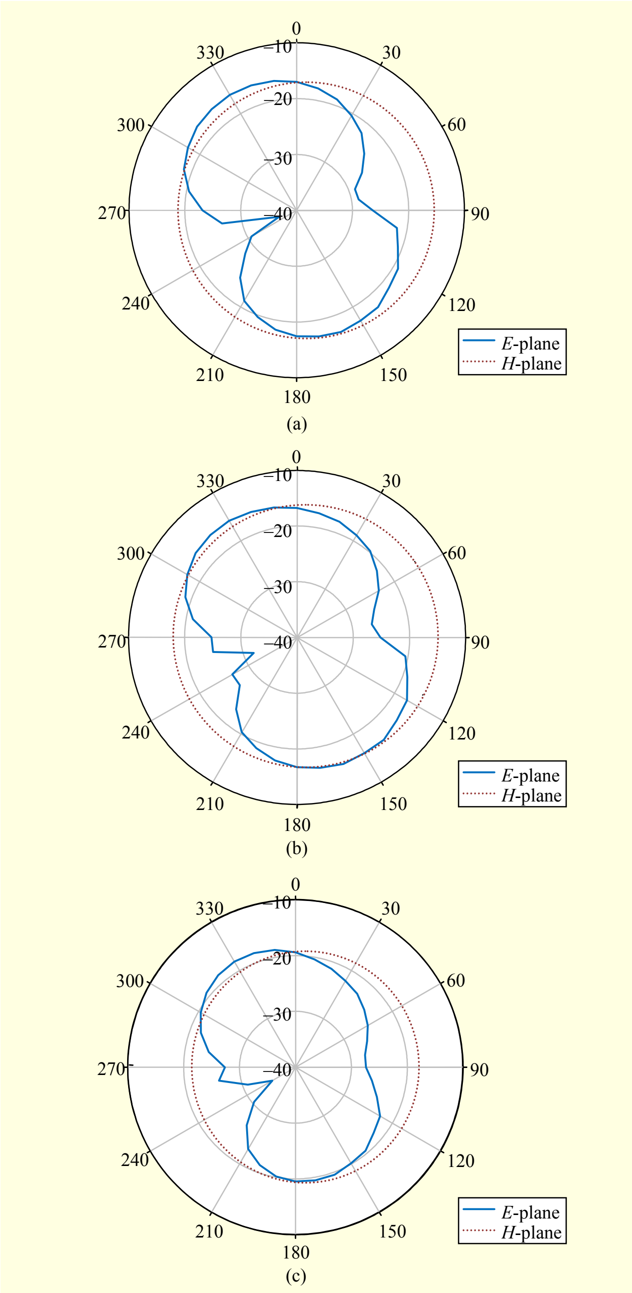

Fig. 6. Measured radiation patterns (*E*-plane: solid and *H*-plane: dotted): (a) 174 MHz, (b) 200 MHz, and (c) 230 MHz.

the PMP mock-up case for the DVB-T band at 174 MHz, 200 MHz, and 230 MHz, respectively. The measured peak gains were –14.3 dBi, –16.2 dBi, and –17.1 dBi, respectively. Figure 7 shows the simulated and measured antenna peak gains for the proposed antenna. Over the DVB-T bands (174 MHz to 230 MHz), the measured antenna gains met the European Telecommunications Standards Institute specification (–25 dBi) for portable internal DVB-T systems [6]. All of the patterns exhibited similar monopole-like, omni-directional radiation characteristics.

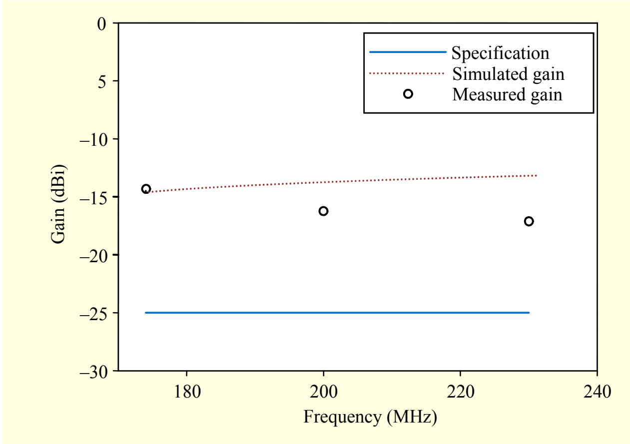

Fig. 7. Simulated and measured antenna gains, satisfying ETSI specifications.

IV. Conclusion

This letter proposed a planar internal DVB-T antenna using a patterned helical line, an open stub, and a matching circuit for PMP applications, and the results were simulated and measured. The proposed antenna is compact, has a very wide frequency bandwidth (from 174 MHz to 230 MHz), and has omni-directional radiation patterns. In addition, the structure of the proposed antenna is very easily fabricated due to the planar configuration. Therefore, the proposed DVB-T antenna should be suitable for internal devices, such as a PMP requiring miniaturization and an aesthetically pleasing appearance.

References

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