Novel Design of A Wideband Folded Monopole Antenna with Parasitic Element for DVB-H Application

Seunggil Jeon · Kwangwoo Ryu · Jaehoon Choi

Abstract

Novel design of a wideband monopole antenna for DVB-H service is presented. The proposed antenna is designed based on a monopole antenna. It consists of folded monopole and parallel parasitic element. The folded segment of the folded monopole makes the antenna shorter. The length of the parasitic element obtains additional resonance frequencies. The gap distance between the folded monopole and the parasitic element is a key parameter to control impedance matching for wideband operation. The antenna has wideband performance, good impedance and radiation characteristics from 470 MHz to 870 MHz. The measured return loss for operating frequencies over DVB-H band is better than 10 dB. Good radiation patterns are also obtained. The measured results are compared with calculated results using Ansoft HFSS(High Frequency Structure Simulator).

Key words : Folded Monopole, Wideband Antenna, Broadcasting Reception.

Ⅰ. Introduction

Recent antenna development for mobile application has focused on the size reduction and multiband/wideband performance to cover multiple services at the same time[1]~[4]. Moreover, the advent of digital broadcasting technologies enables portable devices to receive broadcasting signals, directly. Various wideband antennas for broadcasting services had been reported[5],[6]. Especially, wideband antennas covering digital video broadcasting -handheld (DVB-H) had been studied. An external antenna for handheld devices[7] employs earpiece cord as an antenna for DVB-H reception. The cable length of a typical earpiece cord is about 1,200 mm long. Input return loss is matched at -5 dB. An internal antenna for laptop applications[8] has the length of antenna about 111 mm. But, it requires extra space of 80×30 mm. This technique is probably not suitable for handheld devices. Internal antenna with modified monopole type for DVB-H applications[9] has antenna length of 160 mm and a return loss of around -1 dB over 470~740 MHz.

In this paper, we propose a novel wideband antenna for DVB-H(Digital Video Broadcasting-Handheld; 470~870 MHz)[10]. Since conventional monopole antenna is thin but not suitable for wideband operation, we introduce a folded monopole antenna with parallel parasitic element. It consists of a folded and unfolded metal plate with a gap between the two metal plates. The folded metal plate has folded and unfolded segments. The parallel parasitic element is unfolded straight metal plate that is connected to ground plane and closed to the folded monopole and can be easily excited parasitically[11]. The parasitic element is utilized to generate higher resonant mode for wideband performance.

Experimental result reveals that the impedance matching of proposed antenna depends upon the gap distance between the two metal plates and frequency tuning can be achieved by adjusting the lengths of metal plate. Details of the antenna design and both theoretical and experimental results are presented and discussed.

Ⅱ. Antenna Design

Fig. 1(a) shows the overall structure of the proposed antenna based on monopole structure. The volume of antenna is 7×7×117 mm. The physical length of antenna is 27 % shorter than $\lambda/4$ at 470 MHz. The proposed antenna is located on the finite metal-plate ground of 160×110 mm including 50 Ω cable line for feeding. Fig. 1(b) shows design parameters and side view of the proposed antenna that consists of folded monopole and parasitic element which is connected to ground.

To reduce the length of the proposed antenna, the folding technique[11] is adapted. Furthermore, the tapering method introduced in [11] is used to improve the bandwidth performance with tapered region of bisected bow-tie shape in Fig. 1(b).

Since, the parasitic element is connected to ground and open-ended at opposite end, it works as a monopole antenna while being excited parasitically by the folded

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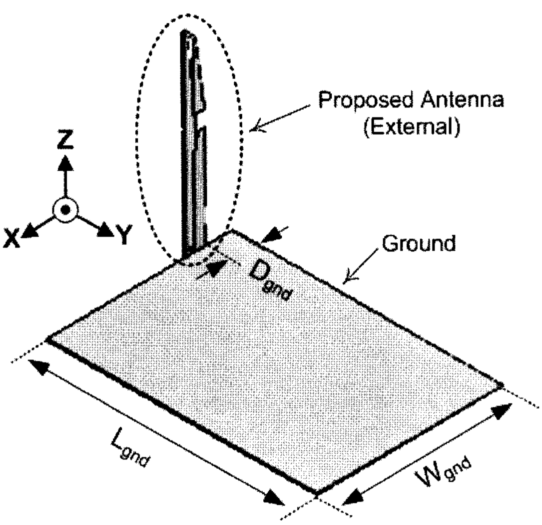
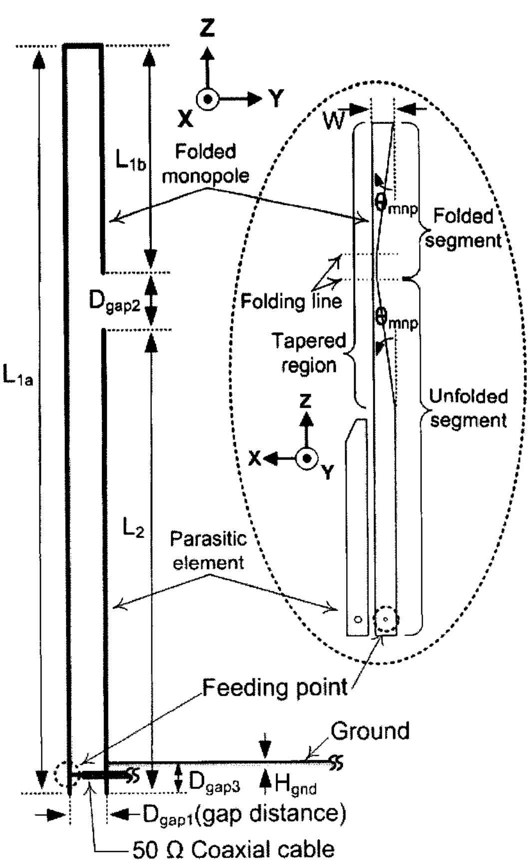
monopole antenna[11]. Initial length can be calculated in term of the wavelength at the operating frequency. The length $L_{1a}+D_{gap1}+L_{1b}$ and L_2 are set to approximately $\lambda/4$ at first and second resonance frequencies, respectively. The optimum design parameter is adjusted from initial parameter values.

Fig. 2(a) shows return loss characteristics for each condition of antenna structure. The proposed antenna has single resonance frequency near 530 MHz while the parasitic element does not exist. Without the folded segment, the proposed antenna has wide bandwidth. However, both of the resulting bandwidths are not enough to satisfy the performance requirement since first resonance frequency is shifted to higher frequency range. In Fig. 2(b), current distributions at each resonance frequencies are performed to define the mechanism of the proposed antenna. Bright region means strong current density and appears on feeding point. Current density on the surface of antenna decreases with increasing distance from the feeding point. Decreasing current densities are appeared

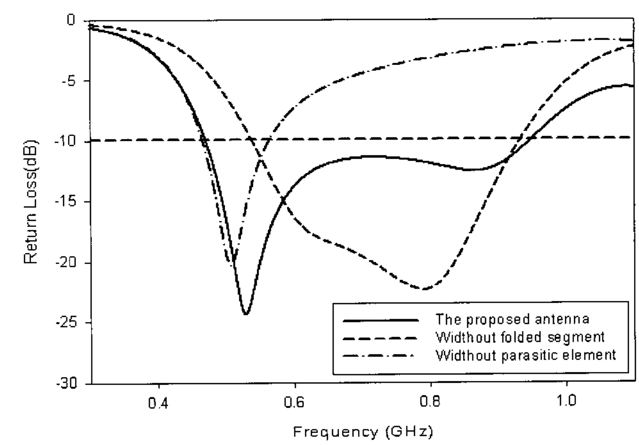


(a) Overall view

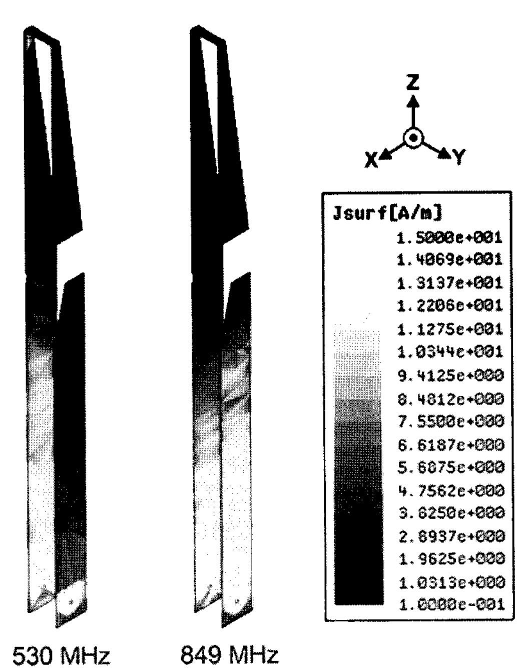


(b) Side view (Folded monopole and parasitic element)

Fig. 1. Structure of the proposed antenna.

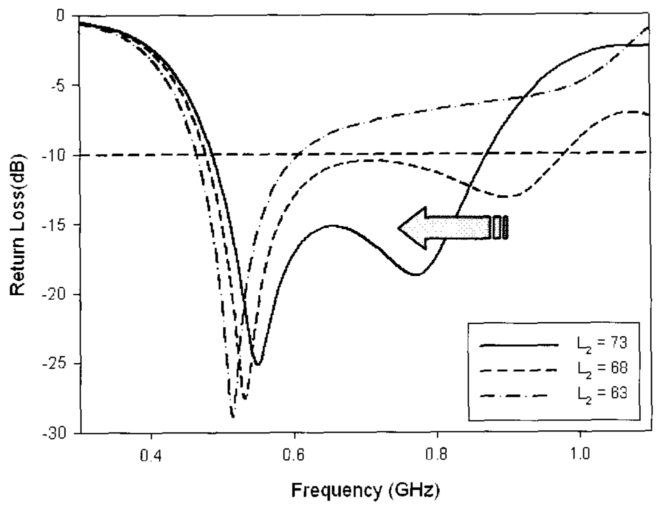


(a) Calculated return loss characteristics for each implement conditions

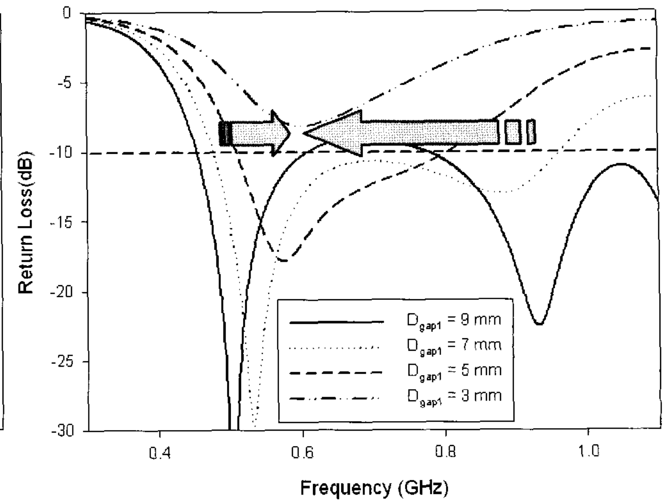


(b) Current distribution and the resonance range at resonance frequencies

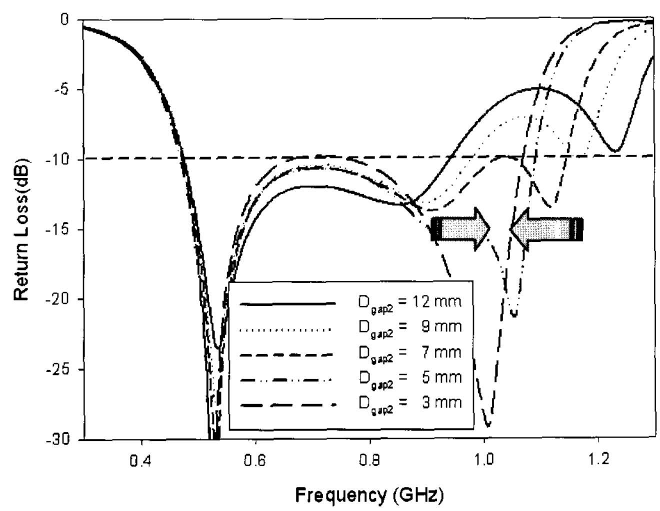
Fig. 2. Mechanism of the proposed antenna.



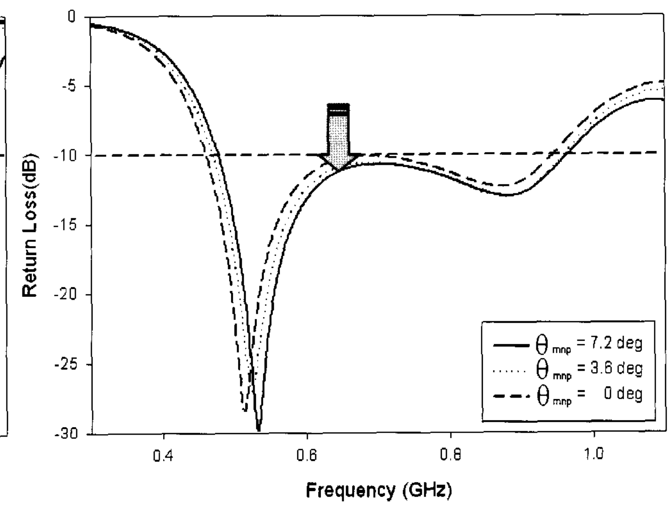
(a) Length of the parasitic element(L_2: L_{1a}=117 mm, D_{gap1}=7 mm, D_{gap2}=9 mm, θ_{mnp}=7.2°)



(b) Gap distance(D_{gap1}: L_{1a}=117 mm, L_2=68 mm, D_{gap2}=9 mm, θ_{mnp}=7.2°)



(c) Gap distance(D_{gap2}: L_{1a}=117 mm, L_2=68 mm, D_{gap1}=7 mm, θ_{mnp}=7.2°)



(d) Tapering angle(θ_{mnp}: L_{1a}=117 mm, L_2=68 mm, D_{gap1}=7 mm, D_{gap2}=9 mm)

Fig. 3. Calculated return loss characteristics for various parameters.

on the surface of the folded monopole and parasitic element at first(530 MHz) and second(849 MHz) resonance frequency, respectively. It indicates that the folded monopole and the parasitic element work as monopole antenna at each of reference frequencies.

The length L_2 of parasitic element plays an importance role to determine the second resonance frequency while the effect on the first resonance frequency is maintained as shown in Fig. 3(a). On the other hand, variation in D_{gap1} alters return loss performance in the first and second frequency bands simultaneously. In Fig. 3(b), shorter distance makes stronger coupled electromagnetic field between folded monopole and parasitic element. It is shown that the folded monopole and parasitic element are strongly coupled and work as united metal plate with narrow gap distance(D_{gap1}). Also, it makes the radiation resistance characteristic of both radiators worse. By optimizing the gap distance(D_{gap1}) and the length of parasitic element(L_2), wide-bandwidth to cover the whole DVB-H service can be obtained. The gap distance is a key parameter to control the matching performance at overall band. Fig. 3(c) shows return loss characteristics for different values of D_{gap2}. The parameter D_{gap2} provides the way to control the second and third resonance frequency band. The third resonance region(1,050 MHz) is the third harmonic frequency of first resonance frequency(530 MHz). However, it is shown that the folded segment and the parasitic element are coupled strongly and work as connected metal plate with narrow gap distance(D_{gap2}). We choose 9 mm to preserve other service bands near DVB-H band. Fig. 3(d) shows return loss characteristics of proposed antenna for different values of θ_{mnp}. The matching performance is improved as θ_{mnp} is longer.

III. Experimetal Result

Design parameters in Table 1 are obtained using simulation software Ansoft HFSS[13]. The length of metal plates (L_{1a}=117 mm and L_2=68 mm) is 82 % and 77 % of $\lambda/4$ at the first and second resonance frequencies occur at about 530 MHz and 849 MHz respectively. The designed antenna is fabricated and radiation characteristics are measured. Fig. 4 shows simulated and measured return loss characteristics for the proposed antenna. The measured 10 dB return loss bandwidth for fabricated antenna is from 461 MHz to 946 MHz (485 MHz). The return loss bandwidth less than 10 dB for broadcasting services is 69 %. The proposed design provides the sufficient bandwidth to cover the DVB-H. Agreement between the experiment and simulation is generally good.

The measured far-field radiation patterns in x-y and y-z planes, at 530 MHz and 849 MHz are shown in Fig. 5.

Table 1. The design parameters.

Parameter	Value	Parameter	Value
L_{1a}	117 mm	D_{gap1}	7 mm
L_{1b}	40 mm	D_{gap2}	9 mm
L_2	68 mm	D_{gap3}	7 mm
L_{gnd}	160 mm	D_{gnd}	16 mm
W_{gnd}	110 mm	H_{gnd}	0.8 mm
W	7 mm	θ_{mnp}	7.2°

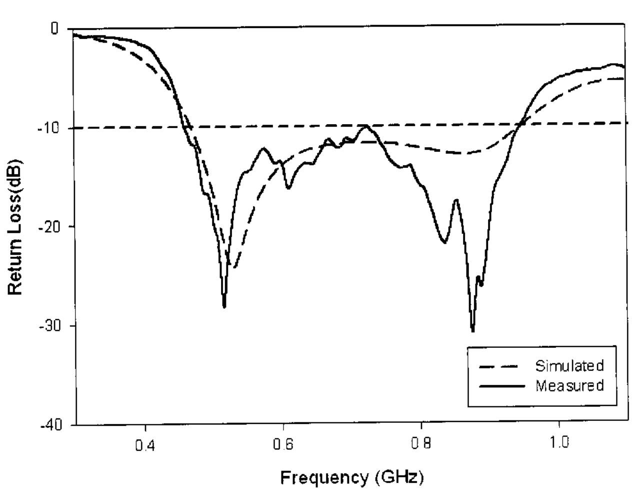
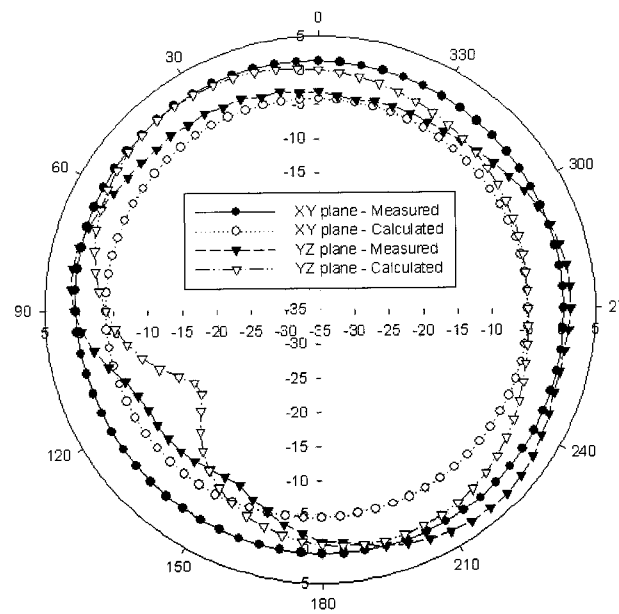


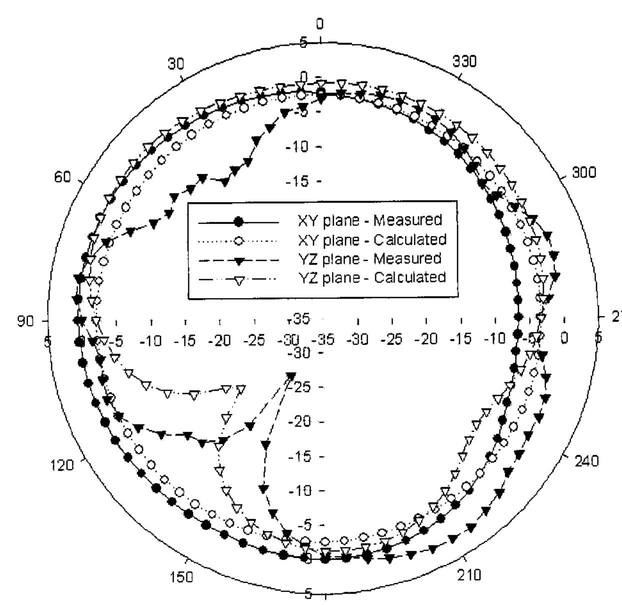
Fig. 4. Calculated and measured return loss of the proposed antenna.

The radiation patterns are nearly omni-directional. As the frequency increases, the electrical size of the ground plane increases and radiation pattern is depressed[12], especially in YZ plane. The measured antenna gain at 530 MHz is 1.58 dBi and one at the 849 MHz is 2.05 dBi.

The measured gain, one of the most important parameters in mobile communication, is shown in Fig. 6. As a reference, the requirement of −10 dBi to −5 dBi gain (470 MHz to 858 MHz) from the implementation guidelines has been included[10]. It is clear that the antenna is well within the specified requirements.



(a) 530 MHz (Measured peak gain 1.58 dBi)



(b) 849 MHz (Measured peak gain 2.05 dBi)

Fig. 5. Far-field radiation patterns for the proposed antenna.

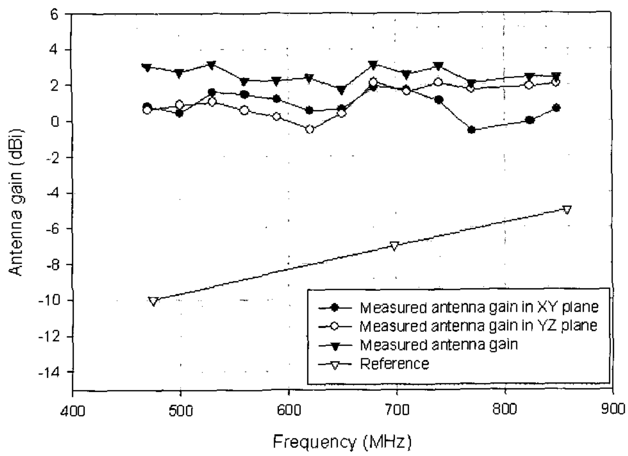


Fig. 6. Comparison between measured antenna gain and typical antenna gain of DVB-H guidelines[10].

Ⅳ. Conclusion

A novel wideband monopole antenna has been proposed and implemented for DVB-H portable applications. The proposed radiating element is a folded monopole with parasitic element. The length of the radiating element is 43 mm shorter than quarter wavelength at 470 MHz. It is 73 % of the quarter wavelength. To obtain the wide bandwidth performance(69 %), the design parameters were optimized by parametric analysis. Numerical and experimental results show that the proposed antenna could be a good candidate for DVB-H applications.

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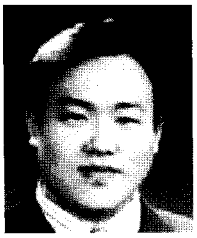

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