## MINIATURIZATION OF PLANAR SPIRAL MONOPOLE ANTENNAS WITH PARASITIC ELEMENTS FOR TERRESTRIAL DMB APPLICATION

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## 1. Introduction

The terrestrial Digital Multimedia Broadcasting (DMB) system is developed for the high quality service of the mobile reception of digital TV on the moving vehicle or in the pocket. Since the terrestrial DMB system uses the VHF signals of about 200 MHz band, it is necessary to design a DMB terminal antenna with extremely small size compared to the wavelength of the signal [1]-[3]. Also, it is required to design the antenna in the planar type to install the antenna in the back side of the terminal case.

In this paper, a miniaturized planar spiral monopole antenna by using the parasitic elements is proposed for the application in the terrestrial DMB terminal. A square spiral monopole antenna is printed on the planar substrate and the parasitic elements with the cross-type and the L-type are printed on the opposite side. The size of the spiral structure for the designed antenna is 50 ㎜×30 ㎜ and the length of the whole antenna is 85 mm (0.058λ). The measured operating frequency is 206 MHz and the bandwidth is about 11 MHz for VSWR≤2. The effect of the substrate thickness on the resonance frequency is also calculated.

## 2. Spiral Monopole Antenna with Parasitic Elements

The spiral wire has been used as a radiating element of the monopole antenna to minimize the size of antenna. In the planar applications, the spiral monopole is printed on the substrate and the antenna size is more reduced due to the substrate permittivity. As a miniaturized radiating element, the meander line is widely employed. Since direction of the current on the meander line are opposite for neighbouring wire, the radiation power is reduced due to the cancellation effect; the antenna gain is very low for miniaturized design of meander antenna. In the spiral structure, the current is in the same direction for neighbouring wire and the radiation efficiency is enhanced.
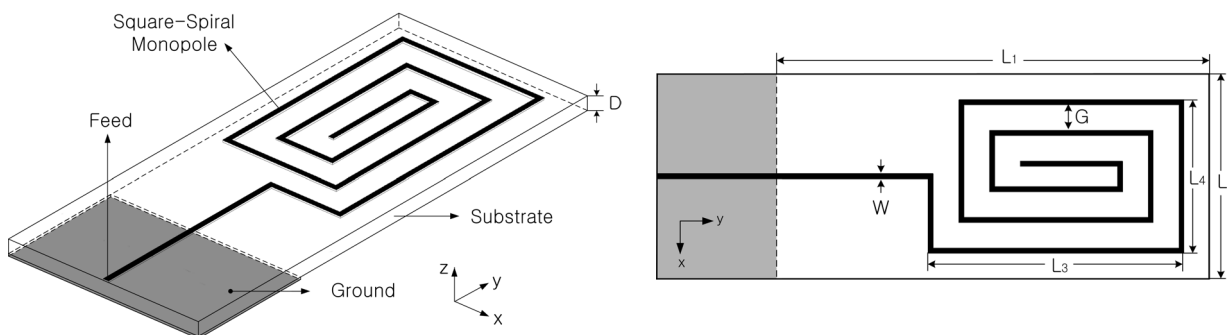


(a) 3D view                                          (b) Top view
Fig. 1. Geometry of square-spiral monopole antenna

Fig. 1 illustrates the structure of the square-spiral monopole antenna. The application of this structure in the DMB terminal is limited because the gain significantly drops for the required size reduction. Fig. 2 shows the configuration of the proposed structure for the miniaturization of the square spiral monopole antenna by using the cross-type and the L-type parasitic elements. The spiral monopole is printed on the top plane of the substrate and the parasitic elements are printed on the bottom plane of the substrate.
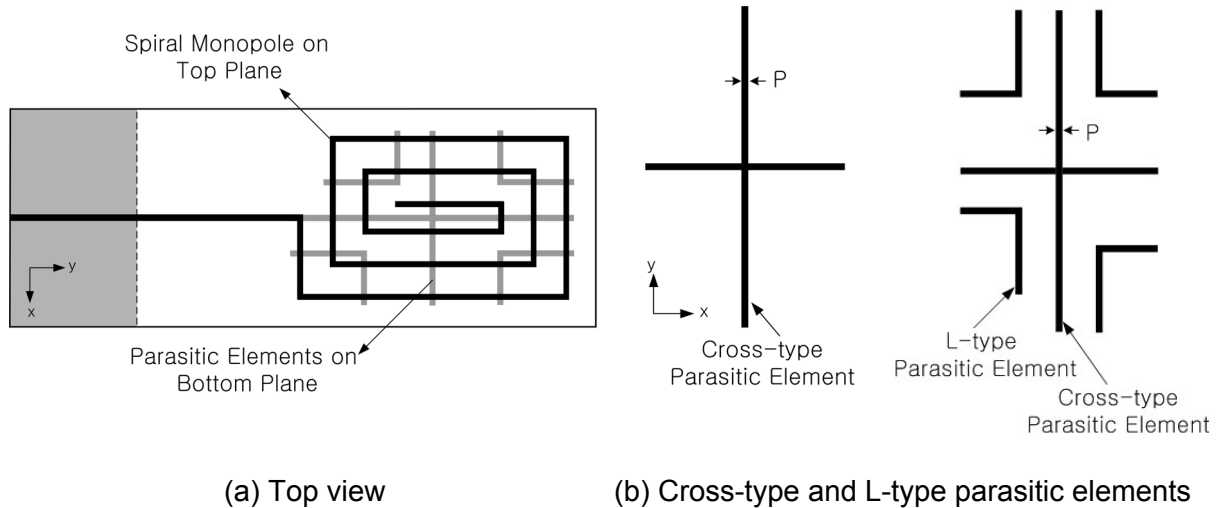


(a) Top view                    (b) Cross-type and L-type parasitic elements
Fig.2. Square-spiral monopole antenna with parasitic elements printed at bottom plane

For the dimensions D=1 ㎜, $L_1$=85 ㎜, $L_2$=40 ㎜, $L_3$=50 ㎜, $L_4$=30 ㎜, W=1 ㎜, P=1 ㎜, and G=5 ㎜, the characteristics of the spiral monopole antenna are calculated. The dielectric constant of the substrate is assumed to be $\varepsilon_r$=4.7, and the simulation is performed by using CST MW studio. The effects of the parasitic elements on resonance characteristics for the square spiral monopole antenna are plotted in Fig. 3(a). For the spiral monopole antenna without parasitic elements, the resonance frequency is 303 MHz. When the cross-type parasitic element is printed on the bottom of the substrate, the resonance frequency is reduced to 240MHz, and it is more reduced to 204 MHz by adding the L-type parasitic element. For the spiral monopole antenna without parasitic elements, the size $L_1$ is 0.085λ and it is 0.068λ for that with cross-type element. When both the cross-type and the L-type elements are installed, $L_1$ is 0.058λ; the size is reduced by 32% compared to the spiral antenna without the parasitic elements.



(a) Effects of parasitic elements          (b) Effects of strip width of parasitic elements
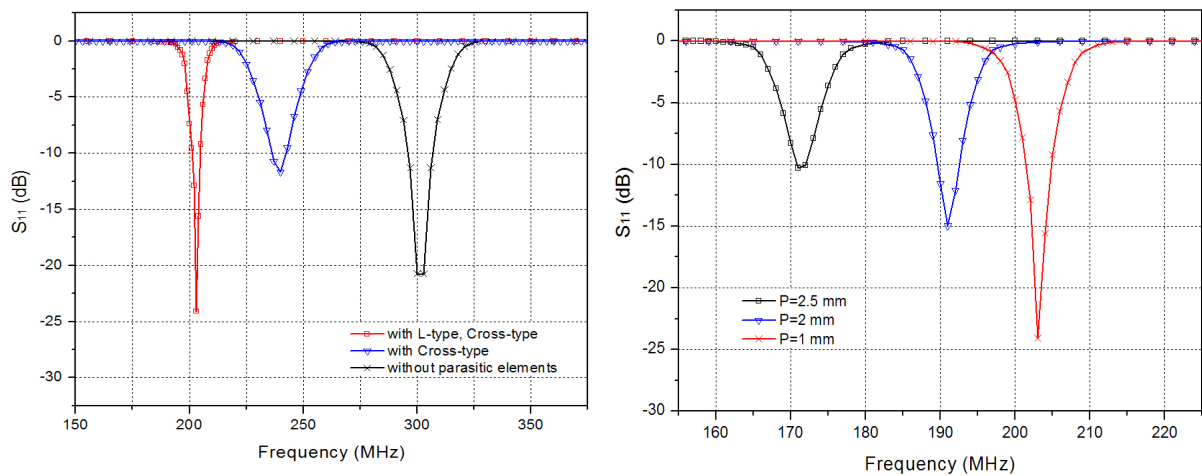Fig.3. Simulated return loss of spiral monopole antennas

In Fig. 3(b), it can be seen that the resonance frequency of the spiral antenna with the parasitic elements decreases when the width of the strip for the parasitic elements P increases. The parasitic element adds the reactive components on the current path of the radiating element and it provides the slow wave effect. As the width of the strip increases, the mutual coupling between the radiating element and the parasitic elements increases.

Fig. 4(a) shows the change of resonance frequency for change in the thickness of substrate D for the spiral monopole antenna without parasitic elements. The resonance frequency decreases as the thickness of substrate increases. Fig. 4(b) plots the resonance frequency versus D for the antenna with parasitic elements. As D increases, the resonance frequency increases since the coupling between the radiating element and the parasitic elements is reduced. Note that the effect of the parasitic element is very small when D is larger than 2 mm. For the thickness of the substrate D is smaller than 1 mm, the resonance frequency changes rapidly with the thickness variation.

The width of the parasitic element P and substrate thickness D have influence not only on the resonance frequency but also on the impedance matching at the resonance frequency. Also, antenna gain is reduced when the antenna size is reduced due to the parasitic elements, it is necessary to find the most fitting parameters through trading off between impedance matching, antenna gain, and antenna size.
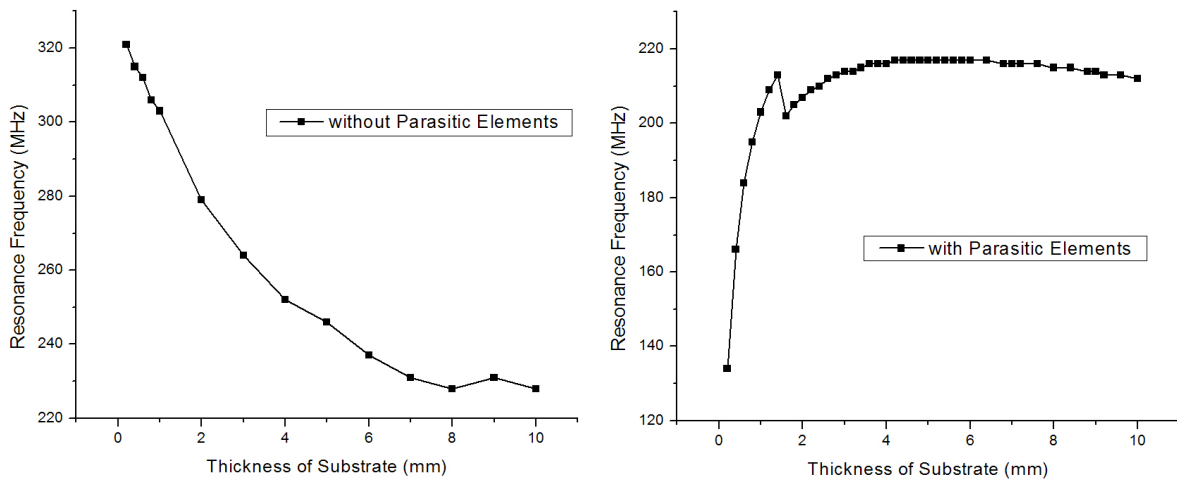


(a) No parasitic elements          (b) With parasitic elements
Fig. 4. Resonance frequency for different thickness(D) of substrate

## 3. Experimental Results

Based on the simulation results, the square spiral monopole antenna with cross-type and L-type parasitic elements is fabricated with FR4 substrate of $\varepsilon_r$=4.7 and D= 1 ㎜. Fig. 5 shows the top and the bottom views of the fabricated antenna. Fig. 6 compares the measured return losses of the spiral monopole antenna without parasitic elements against those when the parasitic elements are installed. The measured resonance frequency of antenna without parasitic elements is about 300MHz. The $S_{11}$ is -16 dB and the bandwidth is 14 MHz for VSWR≤2. The measured resonance frequency for the antenna with the cross-type and the L-type parasitic elements is 206 MHz. At the resonance frequency, $S_{11}$ is smaller than -24 dB. The bandwidth is 11 MHz for VSWR≤2 and the bandwidth decreases for smaller antenna.

The fig. 7 illustrates the measured patterns of the fabricated antenna with the dummy receiver with the size of 90 ㎜ ×75 ㎜ as a ground. With the dummy receiver, the resonance frequency shifts to 240 MHz. Fig. 7 shows the radiation patterns measured in E-plane and H-plane. The measured antenna gain is -0.29dBi.
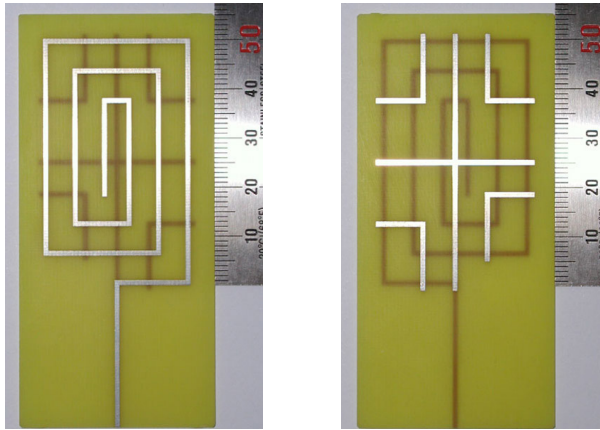
(a) Front view          (b) Bottom view
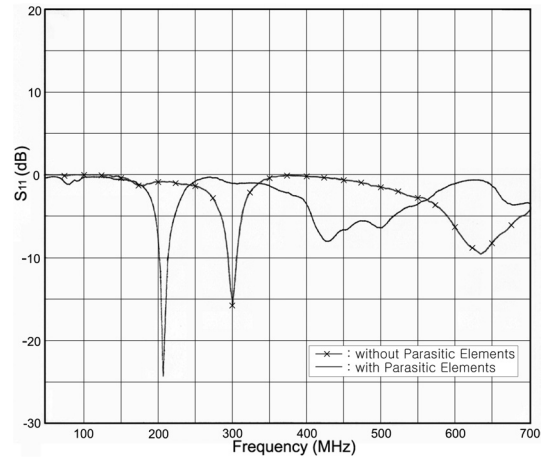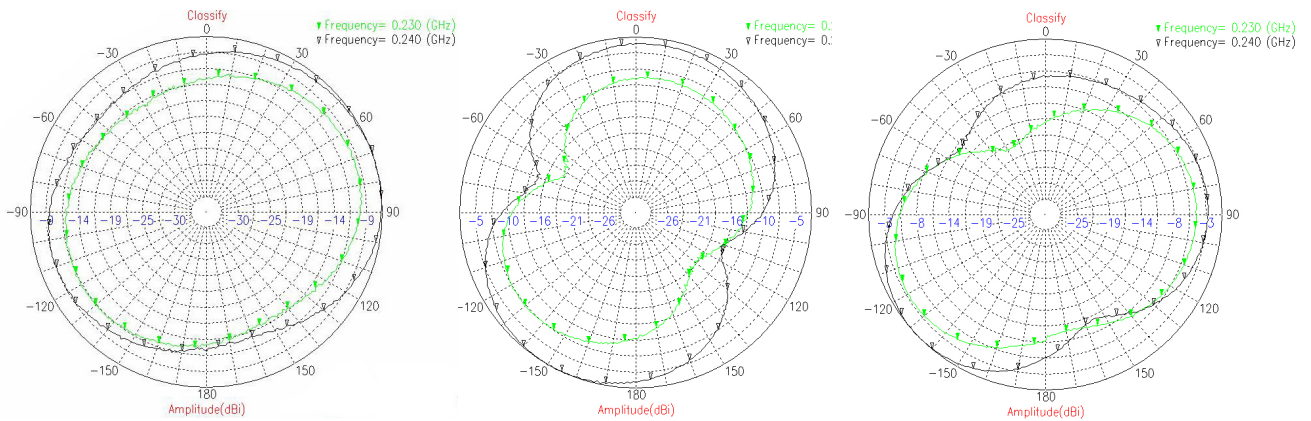Fig. 5. Fabricated antenna



Fig. 6. Measured return loss



(a) E-plane(x-y plane)          (b) E-plane(y-z plane)          (c) H-plane(x-z plane)
Fig. 7. Measured radiation patterns

## 4. Conclusion

A new method for the miniaturization of the spiral monopole antennas are presented by installing parasitic elements on the opposite side of the substrate. The size reduction is satisfactory without serious loss of the antenna gain and the proposed method may be applicable in the design of the small antennas for the mobile DMB terminal

References

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