Characteristic Mode Analysis of U-Shaped Folded Dipole Antenna for WiMAX

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***Abstract*—U-Shaped Folded Dipole Antenna (UFDA) have been proposed for WiMAX. UFDA element is placed on the ground plane so that the occupied volume of the UFDA element is reduced as much as possible. In this paper, Characteristic Mode Analysis (CMA) is used for the analysis of UFDA, which is composed of UFDA element and the ground plane. As a result, it is found that two types of modes in the resonance of UFDA occur. The one is the mode of UFDA element and the other is the mode of the ground plane. Two frequency bands of WiMAX can be covered, when the shape of UFDA is adjusted by using the result of CMA.**

Keywords—Small Antenna, Characteristic Mode Analysis, U-Shape Folded Dipole Antenna

I. INTRODUCTION

In the previous study, we have proposed an antenna which is placed compactly inside a WiMAX (World Interoperability for Microwave Access) device, and called U-Shaped Folded Dipole Antenna (UFDA). By using a suitable objective function in PSO (Particle Swarm Optimization), UFDA was designed to cover completely two frequency bands of WiMAX (2.3~2.7 GHz and 3.4~3.8 GHz) for $S_{11} \leq -6$ dB. Furthermore, the physical antenna volume was reduced by 23.1% as compared with the previously optimized UFDA [1]. However, antenna design by using PSO could only obtain the final shape of the antenna without fully understanding the physical mechanisms of each part of the antenna.

Recently, Characteristic Mode Analysis (CMA) was known as an effective method, which helps in finding the eigenmodes of conductors, and utilized in various mobile handset antenna design[2]-[5]. In this study, we utilize these advantageous features of CMA to analyze the separated part of antenna including UFDA element and the finite Ground Plane (GP). As a result, it is found that two types of modes in the resonance of UFDA occur. The one is the mode of UFDA element and the other is the mode of the GP. Two frequency bands of WiMAX can be covered, when the shape of UFDA is adjusted by using the result of CMA.

II. ANTENNA STRUCTURE

Fig.1 shows the structure of UFDA on the finite GP that represents a shielding plate used in the handset unit. The size of the GP is considered to be able to install inside a WiMAX terminal device, with the overall length of GP of 75 mm × 31 mm. UFDA has a folded dipole element bent into U-shape and placed along the upper end of the GP. The UFDA element is fed by a coaxial cable at the feeding point, which is the center point of the lower edge of feeding strip, and connected to the GP at the shorting strip. And they are made of copper plates with a thickness of 0.3 mm.

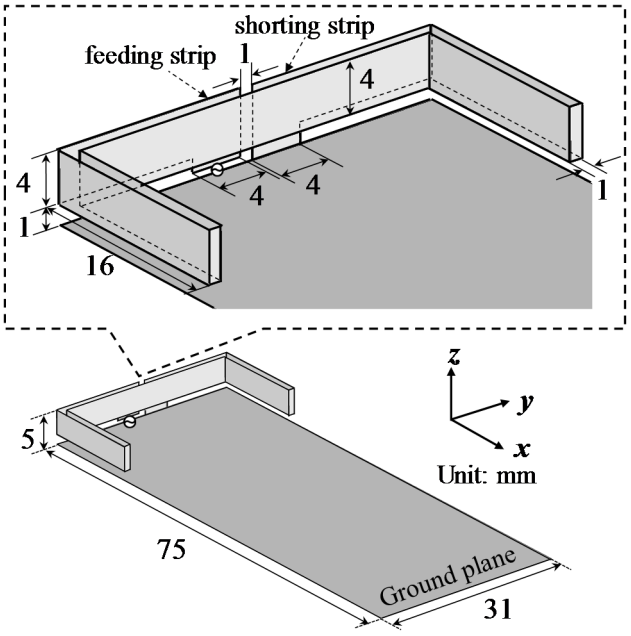


Fig. 1. The structure of UFDA

III. ANALYTICAL RESULTS

In this study, the simulator CST- MW STUDIO is used for the calculation. First, two parts of UFDA are separated and analyzed independently. After determining the resonant frequencies and characteristics (broadband or narrowband) of modes of these separated parts, we combine them to return the initial model, then analyze with CMA. Finally, by comparing the same features of modes at different frequencies among the separated parts and the combined model, the influential modes of each part can be recognized.

A. *Modes of GP only*

Fig.2 shows the model significance (MS) of the GP only. The modes are tracked from 1 to 5 GHz including frequency bands of WiMAX. A mode will be defined as a resonance where its model significance (MS) = 1. As can be seen, two resonances appear at the frequency of 1.7 GHz (Mode1) and 3.9 GHz (Mode 2). And we can know that both of them have large bandwidth defined by MS > 0.707 [6]-[7].

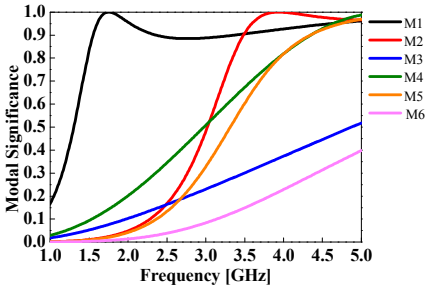


Fig. 2. Modal Significance (MS) of the GP only

B. *Modes of UFDA Element only*

Fig.3 shows the MS of the UFDA element only. We know that, three resonances (MS = 1) appear at the frequency of 1.8 GHz (Mode3), 2.8 GHz (Mode4) and 5.1 GHz (Mode5). Compared to the resonances of GP only, three resonances of UFDA element only have narrower bandwidth than the resonances of the GP only defined by MS > 0.707.

C. *Modes of the Combined Model*

Fig.4 shows the MS of the combined model (GP and UFDA element) without feeding. By analyzing the combined model, four resonances are defined including 1.9 GHz (Mode1), 3.2 GHz (Mode2), 2.5 GHz (Mode3) and 4.4 GHz (Mode4). With the same way to examine the characteristics of each resonance, we can realize that Mode1 and Mode2 of the combined have large bandwidth similar to Mode1 and Mode2 of the GP only shown in Fig.2. Meanwhile, Mode 3 and Mode 4 of the combined have narrower bandwidth similar to Mode 3 and Mode 4 of the UFDA element only shown in Fig.3.

By observing these bandwidth similarities in the aspect of modes, we could recognize which mode is mostly influenced by which separated part of antenna. However, resonant frequency of each mode had shifted when the UFDA element and the GP are combined. Thus, the validity of them were confirmed by comparing the surface current distribution and radiation pattern at each resonant frequency of mode between separated parts and the combined model are shown as Fig. 5, 6, 7, 8 (a) and (b), respectively. As can be seen that, although resonant frequencies at each mode had shifted, there are not only these bandwidth similarities but also similar in surface current distribution and radiation pattern to the modes of them. Therefore, the validity of the mode, which is influenced by the separated parts of UFDA could be confirmed.

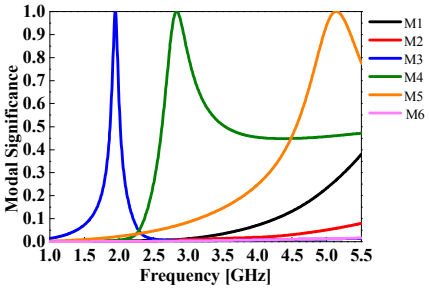


Fig. 3. Modal Significance (MS) of the UFDA element only

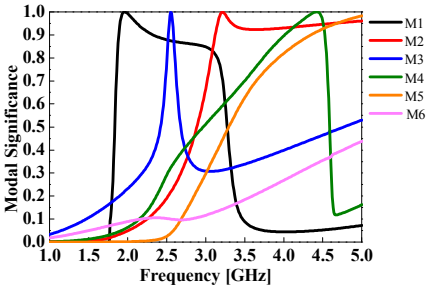


Fig. 4. Modal Significance (MS) of the combined model

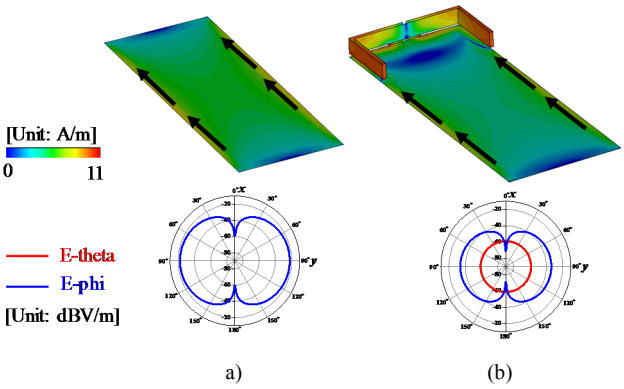


Fig. 5. Current distribution and radiation pattern of *xy* plane at (a) 1.7 GHz (Mode1 of GP only), (b) 1.9 GHz (Mode1 of combined model)

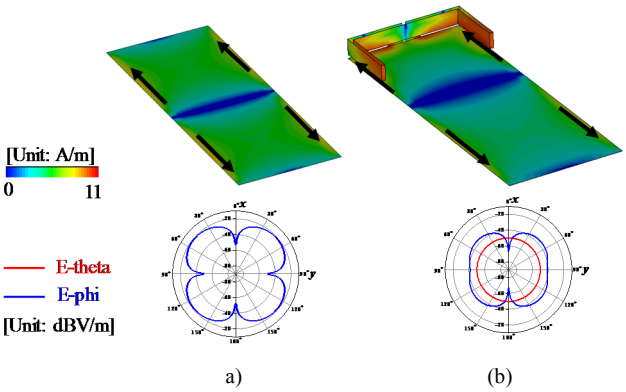
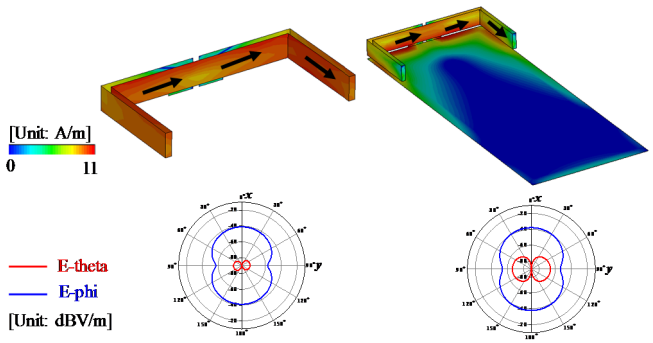
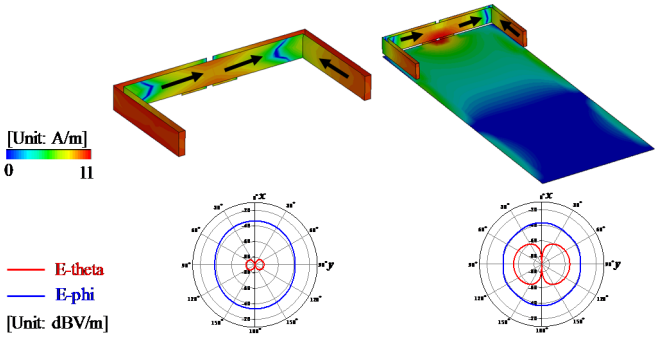


Fig. 6. Current distribution and radiation pattern of *xy* plane at (a) 3.9 GHz (Mode2 of GP only), (b) 3.2 GHz (Mode1 of combined model)



a) (b)

Fig. 7. Current distribution and radiation pattern of ***xy*** plane at (a) 1.8 GHz (Mode3 of UFDA element only), (b) 2.5 GHz (Mode3 of combined model)



a) (b)

Fig. 8. Current distribution and radiation pattern of ***xy*** plane at (a) 2.8 GHz (Mode3 of UFDA element only), (b) 4.4 GHz (Mode3 of combined model)

IV. Conclusion

By utilizing the advantageous features of CMA to analyze each separated part of the antenna, we gave further illustrations of the specific influential modes for separated parts of it including both the GP and the UFDA element. It is confirmed that there are two types of modes of UFDA. The first one consists two modes at 1.9 GHz and 3.2 GHz, affected mostly by the GP. While, the other includes two modes at 2.5 GHz and 4.4 GHz, mainly affected by UFDA element. Subsequently, by using these results, the shape of the GP and the UFDA element would be independently and properly adjusted to cover completely two frequency bands of WiMAX.

References

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