Fundamental Characteristics of Planar Folded Dipole Antenna with a Feed Line

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1. Introduction

Recently, the various services (IMT-2000, Bluetooth, W-LAN, WiMAX) for the cellular phone are widespread. Therefore, the broadband antenna for handsets is required. As one of the broadband antennas, the U-shaped Folded Dipole Antenna (UFDA) has already been introduced and its characteristics has been analyzed in the previous paper [1][2]. A Folded Dipole Antenna (FDA) can be placed close to the Ground Plane (GP) because it has a high radiation resistance. In addition, FDA has the self-balanced effect, which means the current on the GP can be effectively reduced, therefore, no balun is needed even if UFDA is fed by unbalanced feed line such as a coaxial cable. Furthermore, UFDA provides three resonance modes by considering the configuration of the feeding portion, and has broadband characteristics. The purpose of this study is to analyze the broadband characteristics of FDA by using the basic Planar Folded Dipole Antenna (PFDA) with a feed line and to introduce the new structure of the three-dimensional FDA which has broadband characteristics and is compact size.

2. Antenna Configuration

The Fig.1 (a) shows the configuration of PFDA with a feed line. The antenna is fabricated on the front side of a substrate with the thickness t and the relative permittivity ε_r. The desired frequency is f_0 and then the wavelength is λ_0. The antenna length is l_a. And the widths of upper and lower elements are w_1 and w_2, respectively. The spacing between the upper and lower elements is s_a. A feed line consists of two parallel lines with the length l_f, the width w_f, and the spacing between two lines s_f.

Fig.1 (b) shows the structure of the Three-Dimensional FDA (3DFDA) with a feed line. The antenna elements is divided into half, where one half side of antenna element is fabricated on the front side of the substrate and the other on the opposite side of the substrate. Each is connected at the center of the upper element though the pinhole of the substrate. A feed line is also fabricated on both sides of the substrate. The basic antenna parameters of 3DFDA with a feed line is the same as those of PFDA with a feed line (Fig.1(a)) except for the spacing of a feed line s_f'. The height of a feed line s_f' is used instead of s_f. At this time, s_f' is equal to t.

Fig.1 (c) shows the structure of the Compact 3DFDA (C-3DFDA) which has meandered feed line with the same overall length l_f and shortened distance between antenna and feeding point (l_f').

3. Analytical Results

In the analysis, a method of moments (MoM) based commercial simulator is employed. All of the relative permittivity in this paper are unity, which means the free space. The fundamental parameters of the antenna element are l_a = 0.54 λ_0 and $w_1 = w_2 = s_a = w_f = s_f = t$ = 0.0062 λ_0. Fig.2 shows the impedance characteristics on the Smith chart and VSWR characteristics of PFDA (Fig.1(a)) when the length of a feed line is changed from l_f = 0 to λ_0/4. In Fig.2 (a), the locus of the impedance characteristics shifts to the left when l_f increases. In Fig.2(b), the VSWR is normalized to 100ohm, and it can be seen that, as l_f become longer, the 2nd resonance approach to the 1st resonance, which results in broadband characteristics.

In order to confirm the effect of a added feed line, we add an LC circuit to PFDA instead of a feed line. The LC circuit has an inductor in series and a capacitor in shunt with FDA. Fig.3 shows the impedance characteristics on the Smith chart and VSWR characteristics when the capacitor value is fixed at 1pF and the inductor value is changed from 1nH to 60nH. We can find that the changes are similar to those of PFDA with a feed line. From these results, a feed line can be considered to work as an impedance transformer.

Fig.4 shows the impedance characteristics on the Smith chart and VSWR characteristics of PFDA with a feed line, 3DFDA with a feed line and C-3DFDA. In Fig.4, s_f' and t are 0.0062 λ_0 and l_f' is 0.043 λ_0. The feed line of C-3DFDA is shortened while maintaining the same spacing between feed lines. The length of l_f' is approximately 17% of that of 3DFDA. In Fig.4(a), the locus of the impedance characteristics shifts to the left when the antenna becomes a three-dimensional structure, and the VSWR characteristics is improved. In addition, C-3DFDA has almost the same bandwidth as 3DFDA even if the length between the antenna and feeding point l_f' is shortened.

Fig.5 shows the calculated radiation patterns of FDA and C-3DFDA expressed by directivity. As can been seen, the directivity of C-3DFDA is almost the same as that of FDA at all the planes.

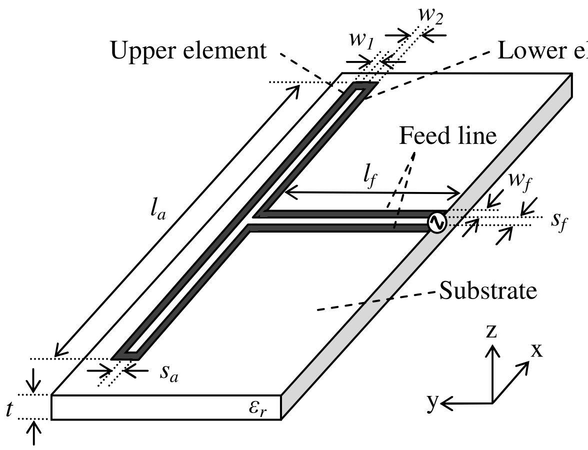
4. Conclusion

In order to research the broadband characteristics of FDA, we investigate fundamental characteristics of PFDA with a feed line. As a result, we confirm that it has broadband characteristics, when the length of a feed line is $\lambda/4$. It is thought that a feed line works as a impedance transformer. And then, C-3DFDA is proposed and analyzed in this paper. The broadband characteristics of C-3DFDA is as same as that of 3DFDA with a feed line in spite of its compact size. This result shows that the antenna in consideration has substantial potential for broadband applications in a small device.

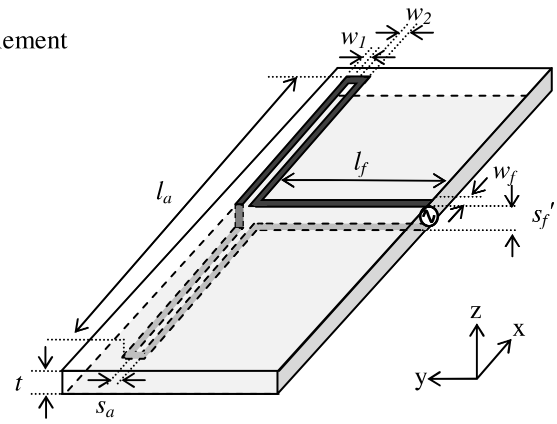
References

[1] A. Kajitani, Y. Kim, H. Morishita, Y. Koyanagi, “Wideband Characteristics of Built-in Folded Dipole antenna for Handsets”, IEEE AP-S Proc., pp.3548-3551, Jun.2007.

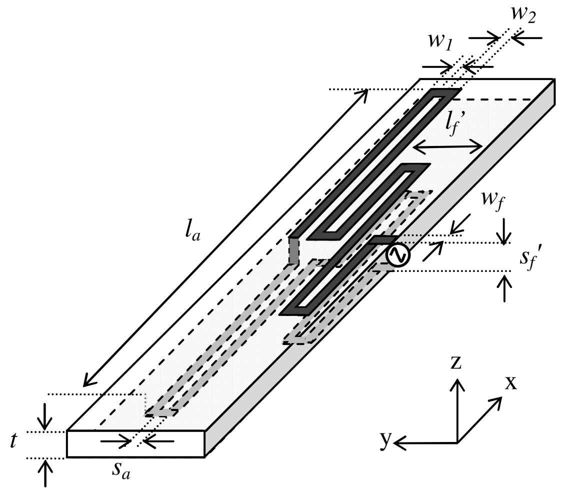
[2] A. Kajitani, Y. Kim, H. Morishita, Y. Koyanagi, ”Characteristics of Built-in Bent Folded Dipole Antenna for Handsets ”, TENCON 2007, ThAP-O4.3, Sep. 2007.



(a) Structure of PFDA with a feed line

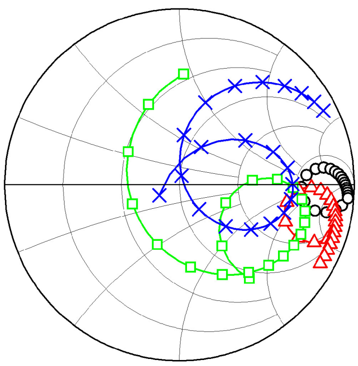


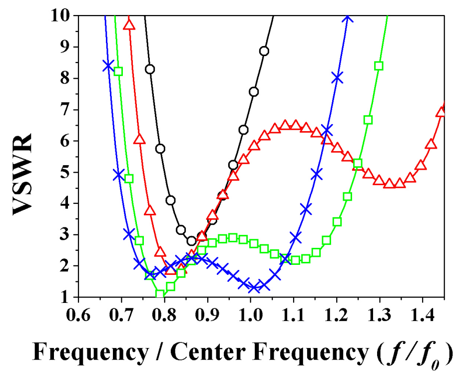
(b) Structure of 3DFDA with a feed line



(c) Structure of C-3DFDA

Fig.1 Antenna Structures





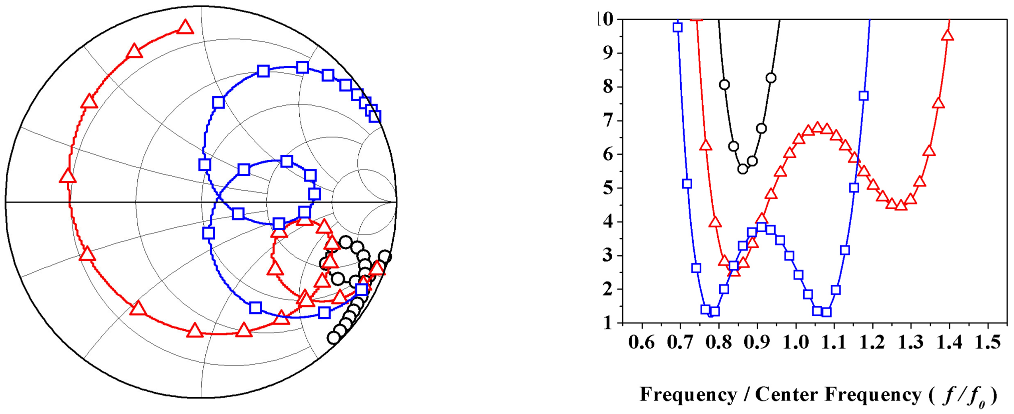
Normalized 100ohm

Start Frequency 0.75 f_0
Stop Frequency 1.25 f_0
Step Frequency 0.015 f_0

-○- $l_f = 0$
-△- $l_f = \lambda_0/8$
-□- $l_f = \lambda_0/5$
-×- $l_f = \lambda_0/4$

(a) Smith chart (b) VSWR

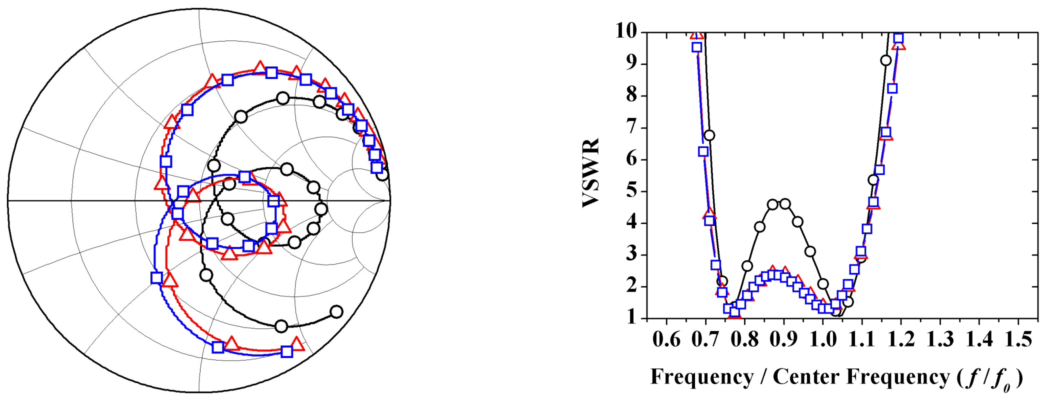
Fig. 2 Input impedance characteristics vs. l_f



Start Frequency 0.65 f_0 -○- L = 1 nH
Stop Frequency 1.45 f_0 -△- L = 30 nH
Step Frequency 0.04 f_0 -□- L = 60 nH

(a) Smith chart (b) VSWR

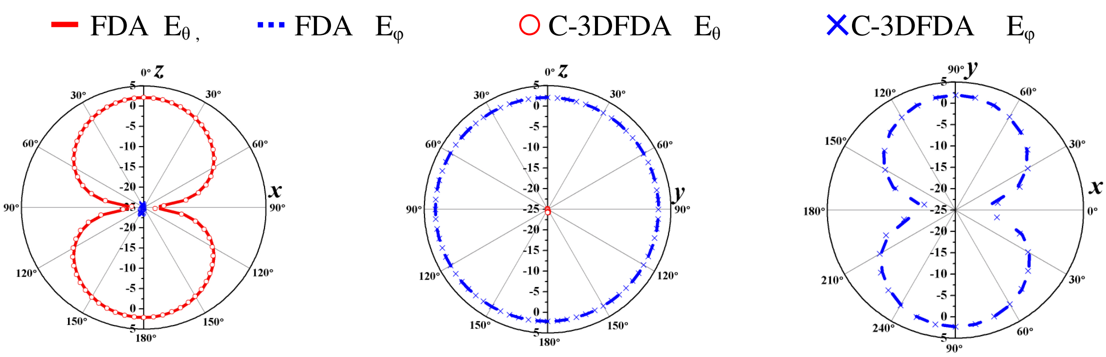
Fig. 3 Input impedance characteristics with an LC circuit



Start Frequency 0.65 f_0 -○- PFDA with a feed line
Stop Frequency 1.45 f_0 -△- 3DFDA with a feed line
Step Frequency 0.04 f_0 -□- C-3DFDA

(a) Smith chart (b) VSWR

Fig.4 Input impedance characteristics among PFDA with a feed line, 3DFDA with a feed line and C-3DFDA



(a) xz-plane (b) yz-plane (c) xy-plane

Fig. 5 Radiation pattern