Simulation Analysis for Broadbanding of Planar Antenna with Three-Frequency Bands

Hiroyasu Matsui [1], Kazuki Miyajima [2], Herman Hideyuki Uchida [3], Toshio Wakabayashi [2]
[1] *Department of Communications Engineering, Graduate School of Information Technology and Electronics, Tokai University,*
1117 Kitakaname, Hiratsuka-city, Kanagawa-prefecture, 259-1207, Japan
[1]*Email: 4aepd005@keyaki.cc.u-tokai.ac.jp*
[2, 3, 4] *School of Information Technology and Electronics, Tokai University,*
1117 Kitakaname, Hiratsuka-city, Kanagawa-prefecture, 259-1207, Japan
[4]*Email: wakaba@dt.u-tokai.ac.jp*

Abstract

Mobile communication technologies have been advanced and many kinds of personal digital assistant (PDA) have been developed. In this paper, we propose planar antennas printed on dielectric substrates, and analyze the characteristics of the basic antenna, such as return loss and radiation pattern, using the FDTD method. In order to obtain broadband characteristic, the modified planar antenna which has semi-elliptical elements are proposed and analyzed. These characteristics are described.

1. Introduction

Growth of the radio communication systems in mobile communication fields is remarkable, and many radio communication systems are in use. Furthermore, the number of frequency-bands increase in wireless communication fields. On the other hands, multi-functionality has also advanced in the development field of PDAs.

In Japan, for example, the cellular phone has additional functions such as a Global Positioning System (GPS) receiver and a TV receiver. Moreover, notebook computers often include a TV receiver and several wireless boards.

In such cases, planar antennas with multi-frequency bands are desired. Small conformal planar antennas are desirable because of their flexible exterior design and ease of carrying.

For the purpose adaptable to multifunctional PDA, the linear element type planar antenna with three-resonance frequency printed on dielectric substrate has been studied. This paper describes our simulation analysis of the new type of planar antennas with three-frequency bands by the FDTD method and their applications for mobile .

Generally, the antenna using a linear type element has the feature that a frequency band is narrow [1] [2]. Linear type planar antennas which have the broadband characteristics for wireless communication systems are desired.

In this paper, a new linear type planar antenna is proposed and analyzed by the FDTD method. Characteristics for the basic structure of new linear type planar antenna are considered for antenna parameters. Furthermore, the modified linear type planar antenna is proposed for the useful antenna of the broadband wireless communication system and also analyzed by the FDTD method.

The antenna of combination of 800MHz band cellular phone, third-generation cellular phone and 2.4GHz band wireless LAN(IEEE802.11b) system is discussed for future wireless communications as an example of application of a new antenna and results are summarized. The broadbanding of the antenna is discussed for the shapes of the antenna elements.

2. Basic Structure of Antenna

Figure 1 depicts the basic structure of a new linear type planar antenna.

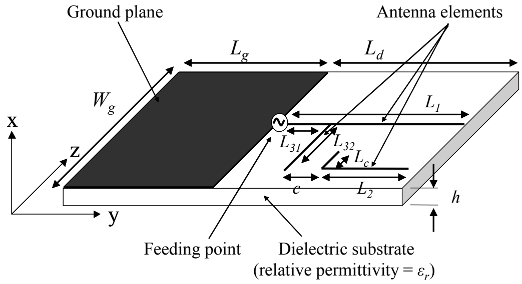


Fig. 1: Basic Structure of New Linear Type Planar Antenna

This antenna structure has the ground plane and the antenna elements on the same side of a dielectric substrate. In this structure, a conductor is printed on the left-hand side of a dielectric substrate as a ground, and the antenna elements are printed on the right-hand side. The feeding point is placed between the ground and the antenna elements. The substrate is L_g+L_d long, W_g wide, and h thick. The antenna consists of three elements. Element 1 is L_1 long and contacts the feeding point. Element 3 consists of two parts that are L_{31} and L_{32} in length. L_{31} is the part of element 1 and L_{32} is the part connected vertically to the element 1. The element 2 has structure which bent to L letter form, and it is consisted by the two parts that are L_2 and L_c in length as shown in a figure.

And the parts of length L_c is on position at a distance c from the element 3.

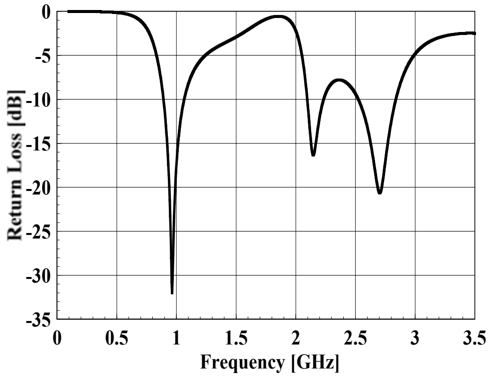
3. Analytical Method

The FDTD method was used to analyze the antenna illustrated in Fig. 1. Cell size is $dx=dy=dz=1$ mm. The analytical domain set so that 20 cells might exit from each side of an antenna. The input is a Gaussian pulse. The PML absorbing boundary condition is applied to boundaries, and it consists of 8 layers. Moreover, the time step satisfies the Courant stability condition:

$$dt \le \frac{1}{c\sqrt{\left(\frac{1}{dx}\right)^2 + \left(\frac{1}{dy}\right)^2 + \left(\frac{1}{dz}\right)^2}} \quad (1)$$

where c=velocity of light.

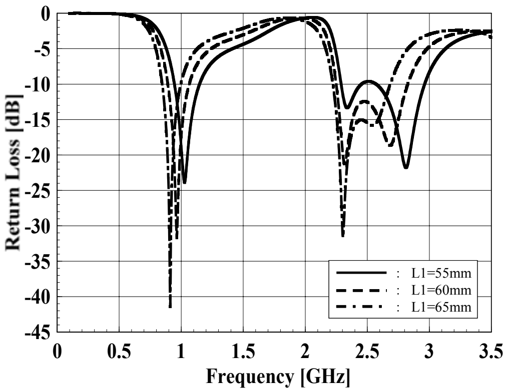
4. Basic Characteristics of Planar Antenna with Three-Frequency Bands



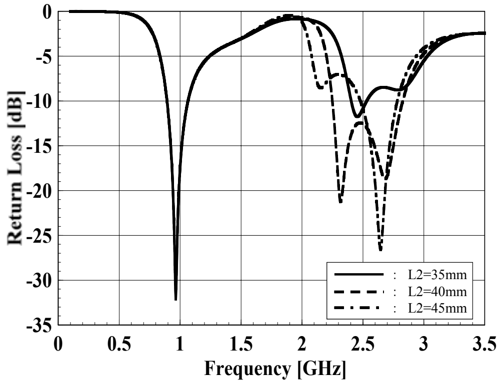
L_g=65, L_d=71, W_g=60, L_1=60, L_2=40, L_{31}=10
L_{32}=10, L_c=3, c=1, h=1mm, ε_r=4.2
Fig. 2: Return Loss Characteristic of Basic Structure

The antenna shown in Fig.1 was analyzed by the FDTD method. Figure 2 plots the return loss. The figure indicates that this antenna has three resonance frequencies.

Fig. 3 shows a change of the return loss when changing only L_1 which is the length of the antenna element 1. This figure shows that the first resonance frequency and the third resonance frequency change, without the change in the second resonance frequency, when changing only L_1. Fig. 4 shows a change of the return loss when changing only L_2 which is the length of the antenna element 2. This figure shows that the second and the third change, without the first resonance frequency changing, when changing only L_2.



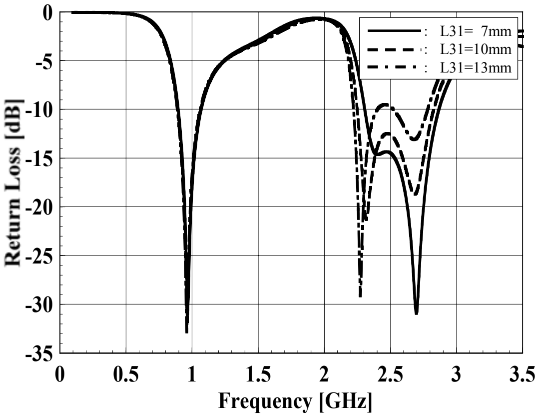
L_g=65, L_d=71, W_g=60, L_2=40, L_{31}=10
L_{32}=10, L_c=1, c=1, h=1mm, ε_r=4.2
Fig. 3: Return Loss Characteristics with changing length of L_1



L_g=65, L_d=71, W_g=60, L_1=60, L_{31}=10
L_{32}=10, L_c=1, c=1, h=1mm, ε_r=4.2
Fig. 4: Return Loss Characteristics with changing length of L_2

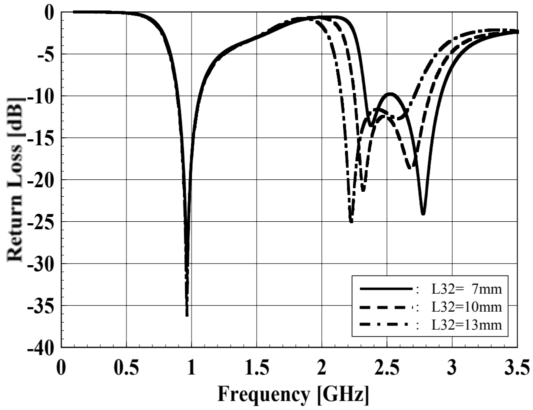
Similarly, a change of the return loss in case of changing only L_{31} is shown in Fig. 5, and a change of the return loss in case of changing only L_{32} is shown in Fig. 6. Moreover, Fig. 7 shows a change of the return loss in case of changing only L_c which is a part of element 2. Figure 5 shows that when changing only L_{31} the second resonance frequency only changes. And figure 6 shows that when changing only L_{32} the second resonance frequency and the third resonance frequency change without the first resonance frequency changing. And when changing only L_c, it turns out that only the second resonance frequency changes, without the change in the first resonance frequency and the third resonance frequency.

These results show that the first resonance frequency depends on L_1. Moreover, the second resonance frequency depends on mainly L_2, L_{32}, and L_c. And the third resonance frequency depends on mainly L_1 and L_{32}.



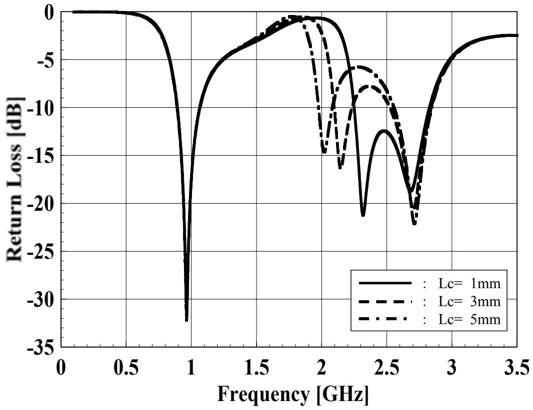
L_g=65, L_d=71, W_g=60, L_1=60, L_2=40,
L_{32}=10, L_c=1, c=1, h=1mm, ε_r=4.2

Fig. 5: Return Loss Characteristics with changing length of L_{31}



L_g=65, L_d=71, W_g=60, L_1=60, L_2=40, L_{31}=10
L_c=1, c=1, h=1mm, ε_r=4.2

Fig. 6: Return Loss Characteristics with changing length of L_{32}



L_g=65, L_d=71, W_g=60, L_1=60, L_2=40, L_{31}=10
L_{32}=10, c=1, h=1mm, ε_r=4.2

Fig. 7: Return Loss Characteristics with changing length of L_c

5. BROADBANDING

Generally, when an antenna is constituted from a linear antenna element, the frequency characteristic has the feature which becomes narrow. So, this paper also examined how to make a broadband characteristic for the proposed planar antenna. In order to make the frequency band wide in the linear type planar antenna, the modified planar antenna is proposed as shown in Fig. 8. In addition, the semi-elliptical shape of elements are shown in Fig. 8

The eccentricity e of the elliptical elements in given by

$$e = \sqrt{1 - \left(\frac{b}{a}\right)^2} \tag{2}$$

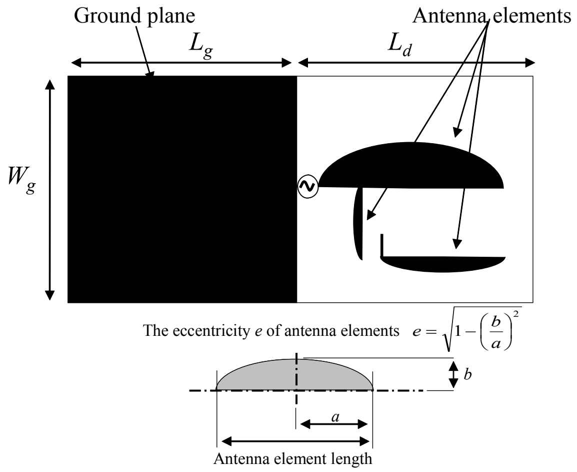
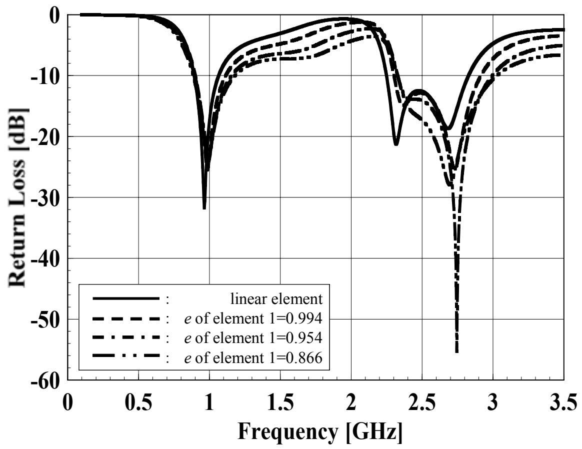


Fig.8: Modified Planar Antenna Structure

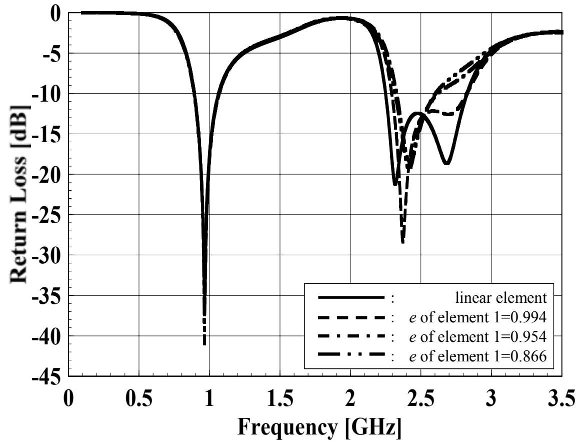
Fig. 9 shows the broadband effect for the frequency band characteristics as a parameter e in the shape of the element 1. This figure shows that in case of changing only the shape of the antenna element 1, frequency band of the first resonance and the third resonance frequencies become broadband, but the return loss characteristics of the second resonance frequency deteriorate.

Fig. 10 shows the broadband effect for the frequency band characteristics as a parameter e in the shape of the element 2. This figure shows that in case of changing only the shape of the antenna element 2, the second resonance frequency becomes broadband, but the return loss characteristics of the third resonance frequency deteriorate. Fig. 11 shows broadband effect for the frequency band characteristics in case of changing only the shape of L_{32} part of antenna element 3. This figure shows that when the shape of L_{32} part is changed, there is no effect for broadband, but it is understood that the return loss characteristics of the second and the third resonance frequencies are improved.



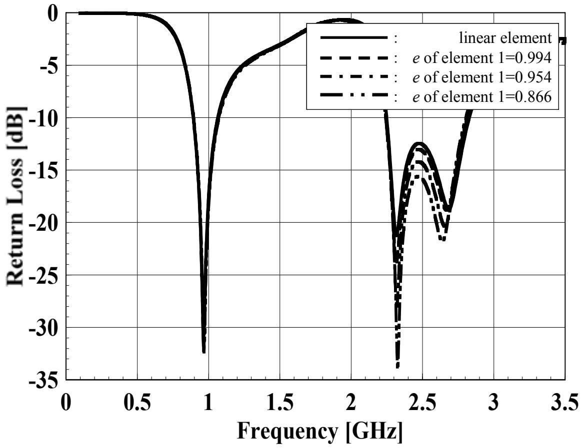
L_g=65, L_d=71, W_g=60, L_1=60, L_2=40, L_{31}=10
L_{32}=10, L_c=1, c=1, h=1mm, ε_r=4.2

Fig. 9: Return Loss Characteristic with Changing Shape of Element 1



L_g=65, L_d=71, W_g=60, L_1=60, L_2=40, L_{31}=10
L_{32}=10, L_c=1, c=1, h=1mm, ε_r=4.2

Fig. 10: Return Loss Characteristic with Changing Shape of Element 2



L_g=65, L_d=71, W_g=60, L_1=60, L_2=40, L_{31}=10
L_{32}=10, L_c=1, c=1, h=1mm, ε_r=4.2

Fig. 11: Return Loss Characteristic with Changing Shape of L32 part

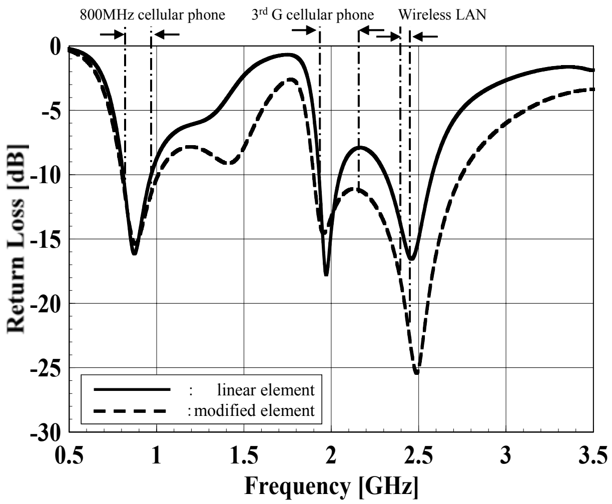
It is found from these results that three resonance characteristic is not maintained only by changing shape of antenna elements simply. Also it is obtained that in order to maintain three resonance characteristic, the balance of eccentricity e of each antenna element is required.

6. Application to Three-Frequency Bands Antenna

The antenna of combination of 800MHz band cellular phone (810MHz – 957MHz), third-generation cellular phone (1.92GHz – 2.17GHz) and 2.4GHz band wireless LAN(IEEE802.11b : 2.40GHz – 2.497GHz) system is considered for future wireless communications as an example of application of the modified antenna.

Therefore, the first resonance frequency is used for the 800MHz band cellular phone, the second resonance frequency is used for the third generation cellular phone, and the third resonance frequency is used for the 2.4GHz band wireless LAN.

Fig. 12 shows the return loss characteristics in case of each resonance frequency application to each radio communications system. Moreover, the characteristic of the planar antenna using a linear type element (linear element planar antenna) and the characteristics of the antenna using the antenna element which modified (modified element antenna) for making it a broadband characteristic are shown in Fig. 12.



- Linear Element Antenna -
L_g=85, L_d=79, W_g=60, L_1=63, L_2=45, L_{31}=12, L_{32}=13,
L_c=2, c=1, h=1mm, ε_r=4.2

- Modified Element Antenna -
L_g=85, L_d=79, W_g=60, L_1=63, L_2=45, L_{31}=12, L_{32}=13, L_c=4, h=1mm,
c=1, ε_r=4.2, *U of element 1* = 0.3, *U of element 2* = 0.1,
U of L32 part = 0.5,

Fig. 12: Return Loss Characteristic of Linear Element Planar Antenna and Modified Element Planar Antenna

In this figure, although each resonance frequency of linear element antenna conforms to each radio communication system, two frequency bandwidths which are 800MHz cellular phone system and the third generation cellular phone system bandwidth are not satisfied. On the other hand, each resonance frequency of modified element antenna conforms to each radio communication system, and frequency bandwidth which is desired for each radio communication system bandwidth is satisfied, too.

Fig. 13 shows the radiation patterns at the first resonance frequency of a linear element antenna and the modified element antenna.

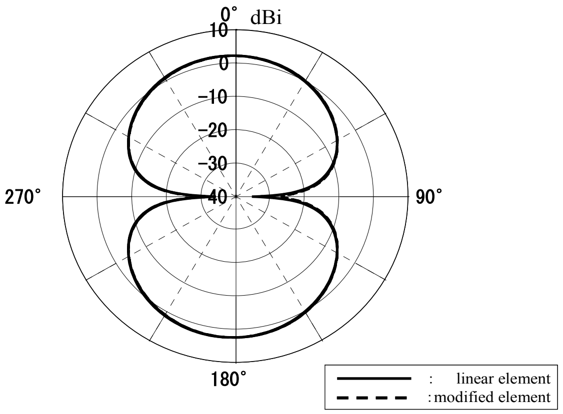
Similarly, Fig. 14 shows the radiation patterns at the second resonance frequency, and Fig. 15 shows the radiation patterns at the third resonance frequency.

These figures show that a linear element antenna and a modified element antenna are almost the same radiation patterns at every frequency.

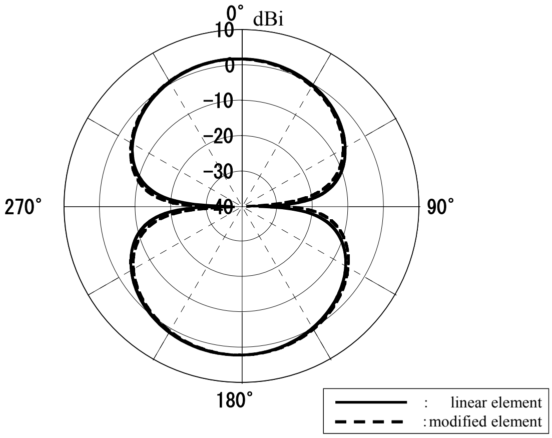
Moreover, the radiation patterns of *xz* plane are mostly omnidirectional radiation patterns at each resonance frequency, and the radiation patterns of both of antennas is the same pattern.

Modifying linear type antenna element to a semi-elliptical shape antenna element in the planar antenna with three-frequency bands, it is obvious that it is possible effectively to make a frequency band to broadband.

Moreover, it can be seen that a new type planar antenna is useful as a three-frequency bands antenna.

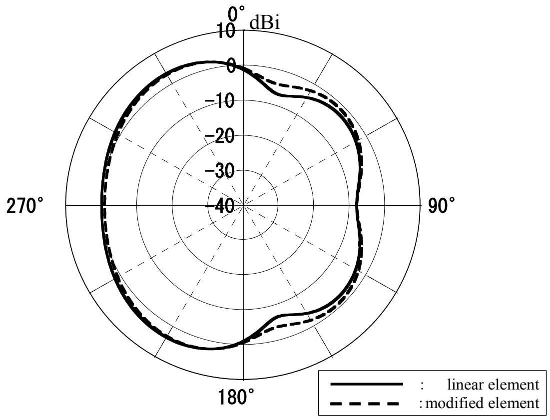


(a) *xy plane*

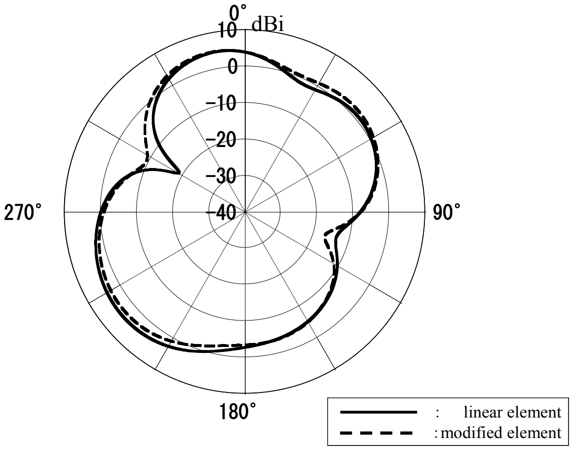


(b) *zy plane*

Fig. 13: Radiation Patterns at the First Resonance Frequency

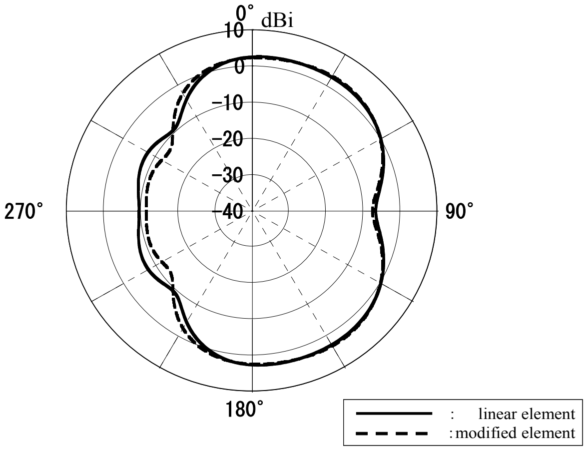


(a) *xy plane*

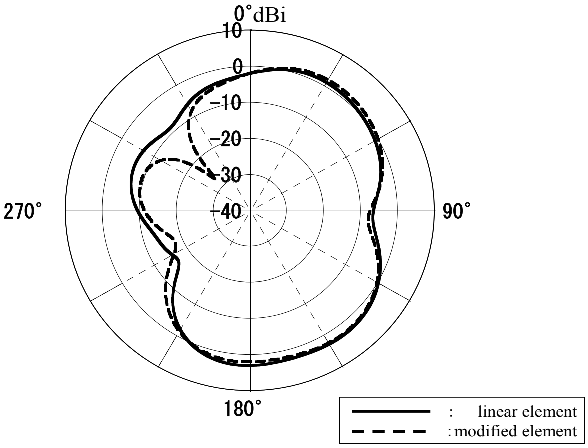


(b) *zy plane*

Fig. 14: Radiation Patterns at the Second Resonance Frequency



(a) *xy plane*



(b) *zy plane*

Fig. 15: Radiation Patterns at the Third Resonance Frequency

7. CONCLUSIONS

The planar antenna with three-frequency bands printed on the dielectric substrate as new linear type planar antenna was proposed. The basic resonance characteristic of new linear type planar antenna was discussed by changing of each antenna element length.

Also, in order to improve a frequency band width characteristic to broadband characteristic, the modified planar antenna with the semi-elliptical shape element was proposed. The effect for a broadband characteristic by modifying the antenna element to semi-elliptical shape for each resonance frequency was considered.

An application of three-frequency bands antenna which combined 800MHz band cellular phone, third generation cellular phone and 2.4GHz band wireless LAN system was shown as an example.

Modifying linear type antenna element to a semi- elliptical shape antenna element in the planar antenna with three-frequency bands, it is obvious that it is possible effectively to make a frequency band to broadband.

Moreover, it can be seen that a new type planar antenna is useful as a three-frequency bands antenna.

REFERENCES

[1] Toshikazu HORI, "*Broadband / Multiband Printed Antennas*", IEICE B, vol. J87-B No.9, pp.1130-1139, Sep. 2004

[2] Narayan Prasad Agrawall, Girish Kumar, and K. P. Ray, "*Wide-Band Planar Monopole Antennas*", IEEE Trans. Antennas Propag., Vol. 46 No.2, Feb. 1998