A Polarization Diversity Antenna for Wireless Terminal

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Abstract

In this paper, we propose a novel type of polarization diversity antenna construction for mobile wireless terminal. This diversity antenna construction is composed of a 180° hybrid and two antenna elements. By changing the relative excitation phase between two antenna elements arranged on both sides of the conducting-plate to in-phase or out-of-phase, the current on the antenna elements and on the conducting-plate is changed. In the above-mentioned method, the proposed antenna can obtain two polarization-modes. Additionally, the correlation coefficient of the radiation pattern between the two modes is very low.

1. Introduction

Since the third generation mobile phone services have been started, the development of antennas having higher diversity gain has been required in order to increase a data communication rate. For this requirement, we studied a polarization diversity antenna construction that is suitable for mobile phones, and can be applied to a combining diversity.

Microstrip patch antenna (MSA) is one candidate to the requirement of the above. It can easily and simultaneously radiates orthogonal polarization by utilizing the modally orthogonal two ports. Moreover, the polarization of the MSA can be selectively changed the shorting posts [1]. However, the patch antennas are not suitable essentially for compact and thin mobile phone, because the planar patch size is approximately half-wavelength, which requires large volume in the mobile phone at frequency bands of the third generation.

Another method has a capability of polarization diversity and suitable size for mobile phones, has been proposed in [2]. However, the method of [2] cannot be applied to a combining diversity.

In this paper, we propose a novel method to realize the polarization combining diversity. The proposed antenna has two antenna elements at the both edge of the conducting-plate. By changing the relative excitation phase between them to in-phase or out-of-phase, the antenna can generate two modes having different polarization. We use the 180° hybrid for the feeding circuit in order to change relative excitation phase.

At first we show that the basic operation principle of the proposed antenna by using FDTD method. Secondly, we show the results of simulations and measurements.

2. Basic Operation Principle

The basic configuration of the proposed antenna is shown in Figure 1. This antenna consists of a conducting-plate, two excitation antenna elements and a feeding circuit. In this calculation, in order to confirm the operation of the proposed antenna, we have calculated current distributions on the conducting-plate and the radiation patterns by using the FDTD. The FDTD simulations are calculated in situation of $L_1=0.77\lambda_c$, $W_1=0.27\lambda_c$, $L_2=0.13\lambda_c$, $W_2=0.1\lambda_c$ where λ_c is the center wavelength of our target frequency-band. And the insertion loss is neglect.

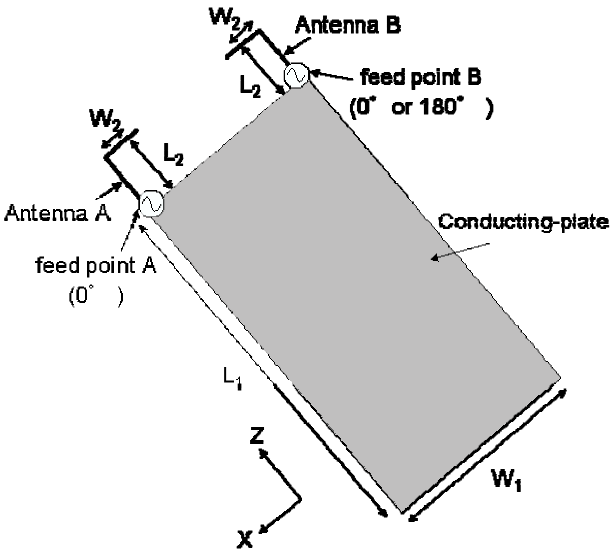
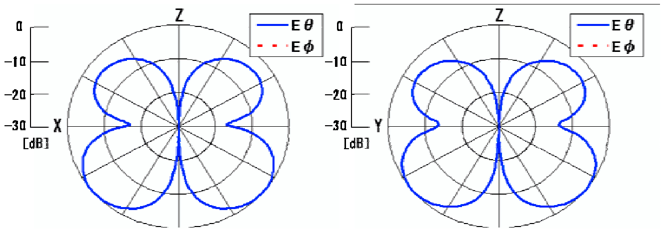


Fig. 1: Calculation model of proposed antenna

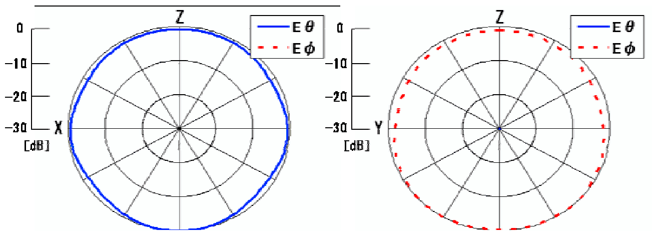
Figure 4 shows the x-component and z-component current distributions of in-phase case. Figure 5 shows the x-component and z-component current distributions of out-of-phase case. The amplitude is normalized by the maximum value. When the two elements are simultaneously excited in-phase, in the proposed antenna, the current in the z-direction becomes the main component. Therefore, a main polarization of the radiation pattern in zy-plane becomes E_θ as shown in Figure 2. On the other hand, when the two elements are simultaneously excited out-of-phase, the current in the x-direction becomes the main component. Therefore, a main polarization of the radiation pattern in zy-plane becomes E_ϕ as shown in Figure 3. Thus, the proposed antenna can generate two polarization modes (z-polarization-mode and x-polarization-mode). In z-y plane, the main polarization component of the radiation field changes. In z-x plane, the shape of the radiation pattern drastically changes. In addition, correlation coefficient ρ between two modes is approximately 0.2 being very low. The correlation coefficients are calculated by following expression.

$$\rho \cong \frac{\left| \int_0^{2\pi}\int_0^{\pi} \left\{ E_{\theta 1}(\theta,\phi)E^*_{\theta 2}(\theta,\phi) + E_{\varphi 1}(\theta,\phi)E^*_{\varphi 2}(\theta,\phi) \right\} \sin\theta d\theta d\phi \right|^2}{\left[\begin{array}{l} \int_0^{2\pi}\int_0^{\pi} \left\{ E_{\theta 1}(\theta,\phi)E^*_{\theta 1}(\theta,\phi) + E_{\phi 1}(\theta,\phi)E^*_{\phi 1}(\theta,\phi) \right\} \sin\theta d\theta d\phi \\ \times \int_0^{2\pi}\int_0^{\pi} \left\{ E_{\theta 2}(\theta,\phi)E^*_{\theta 2}(\theta,\phi) + E_{\phi 2}(\theta,\varphi)E^*_{\phi 2}(\theta,\phi) \right\} \sin\theta d\theta d\phi \end{array} \right]}$$



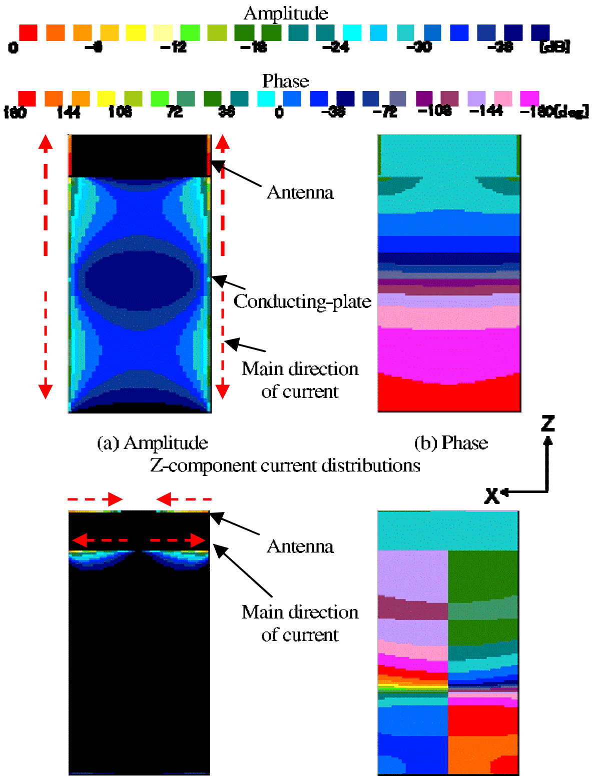
z-x plane z-y plane

Fig. 2: Radiation pattern (in-phase case)



z-x plane z-y plane

Fig. 3: Radiation pattern (out-of-phase case)



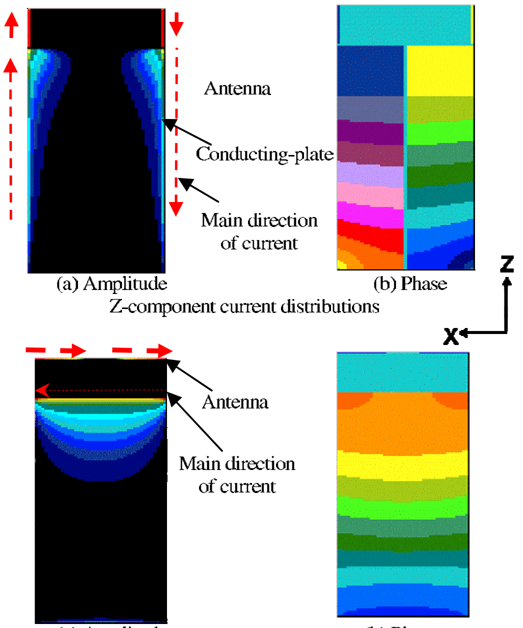
(a) Amplitude (b) Phase

Z-component current distributions

(a) Amplitude (b) Phase

X-component current distributions

Fig. 4: Current distributions (in-phase case)



(a) Amplitude (b) Phase

Z-component current distributions

(a) Amplitude (b) Phase

X-component current distributions

Fig. 5: Current distributions (out-of-phase case)

3. EXPERIMENT

Figure 6 shows the configuration of the prototype. The situation of prototype is following, $L_1=0.77\lambda_c$, $W_1=0.27\lambda_c$, $L_2=0.13\lambda_c$, $W_2=0.05\lambda_c$, $D_1=0.004\lambda_c$, $D_2=0.006\lambda_c$. Also the electric characteristic of the substrate is following, $\varepsilon_r=4.2$ and $\tan\delta=0.024$. Moreover, The 180° hybrid designed on the distributed constant circuit of Rat-Race type is arranged on the conducting-plate.

Figure 7 and 8 show the input impedances of the calculations and the measurements. It can be confirmed that both are almost corresponding.

Figure 9 and 10 show the radiation patterns of the calculation results and measurement results when port1 or port2 is excited, respectively. The radiation patterns of each main polarization component in z-x plane and z-y plane have good agreement between the calculation and the measurement. In addition, correlation coefficient of the radiation patterns between two modes is 0.27. It is almost corresponding to the calculation one (0.21).

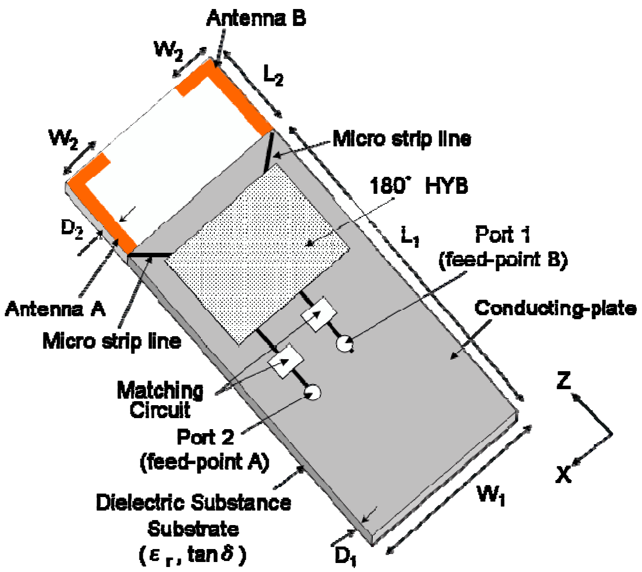


Fig. 6: Prototype

4. CONCLUSION

We have proposed a novel type of polarization diversity antenna construction suitable for mobile phones and applicable to synthesis diversity. We have confirmed the basic operation principle of the proposed antenna by the simulation and the measurement. In measurement, the proposed antenna obtains two radiation modes being different from each other. Also, the correlation coefficient between two modes is low value 0.27. Our next important works are to miniaturize the 180° hybrid by using a lumped element.

REFERENCES

[1]R. Vaughan, "Microstrip Antennas with Frequency Agility and Polarization Diversity", *IEEE Trans*, vol.AP-29, no.1, pp.118-123, Jan. 1981

[2] Y. Nishioka et al., "One-element Diversity Antenna with Reactance-Switching Circuit for Mobile Phones," *Antennas and Propagation Society International Symposium*, vol.3, pp.3175-3178, June 2004

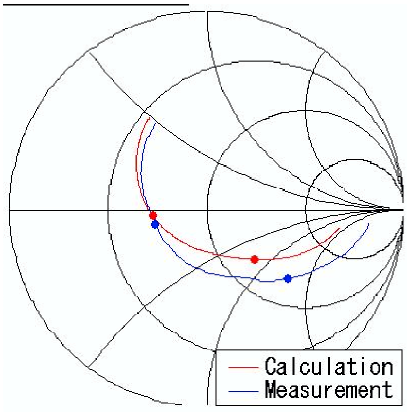


Fig. 7: Input impedance (port1: in-phase case)

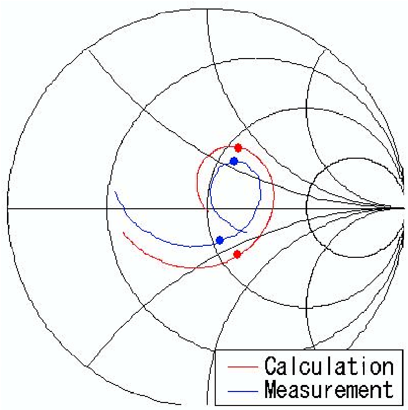
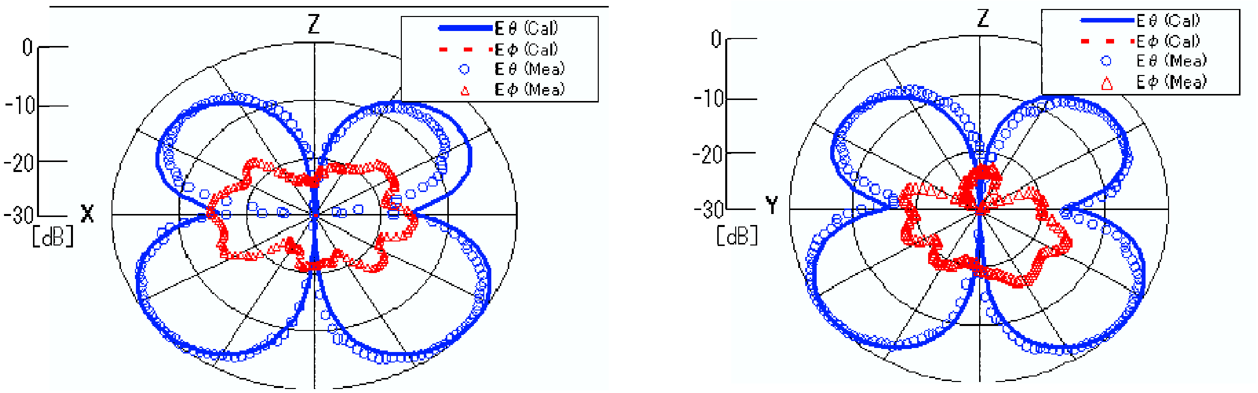


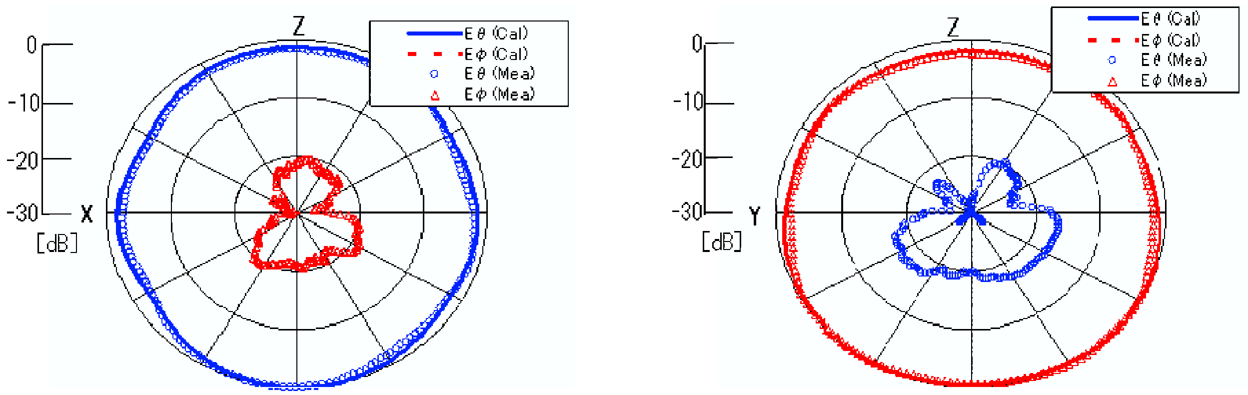
Fig. 8: Input impedance (port2: out-of-phase case)



z-x plane

z-y plane

Fig9: Radiation pattern (in-phase case)



z-x plane

z-y plane

Fig10: Radiation pattern (out-of-phase case)