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One-Branch Diversity Antenna Construction Using Reactance-Switching Circuit for Portable Telephones

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1. Introduction In land mobile communication systems, it is well known that the multi-path fading frequently degrade the communication quality. In order to suppress the degradation of the communication quality due to the fading, antenna diversity techniques have widely been implementing in base and mobile stations. In mobile portable telephones, two-branch antenna diversity technique has commonly been implementing and been well studied [1]-[5]. This needs for install two antenna elements to the mobile phone, and requires large volume for installation. However, the reduction of the installation space for antenna elements is strongly required to achieve the miniaturized and thin mobile phone. In addition, an internal or protuberanceless antenna structure is also required from a view point of the appearance of the mobile phone.

One of the most effective ways for these requirements is to reduce the number of antenna elements without lacking diversity effects. In [6] and [7], one-element antenna diversity implementations using microstrip patch antennas with several shorting posts consisting of a conducting-wire and a PIN-diode have been studied. However, the patch antennas are not suitable essentially for compact and thin mobile phone, because the planar dimension of the patch is approximately half-wavelength, which requires large volume inside the mobile phone at a frequency less than S-band.

In this paper, we propose a novel type of diversity antenna construction for compact mobile phones with an internal type of antenna structure. The validity of the proposed diversity antenna construction will be shown numerically and experimentally. All the calculated results to be shown in this paper are obtained by using the FDTD method.

2. Diversity Antenna Construction Figure 1 shows the geometry of the antenna considered here. This structure represents the implementation of the proposed diversity antenna construction in a foldable mobile phone that is the most popular type in recent Japan. The antenna consists of two conducting-plates (GND 1 and 2), the conducting-plate 3 connecting between the GND 1 and 2, one excitation element, and the reactance-switching circuit, Z, connecting between the excitation element and the GND 1. The GND 1 simulates the ground-plane of RF and baseband circuits. The GND 2 simulates the ground-plane of circuits for a display.

The idea of the diversity antenna construction we propose is qualitatively explained below. We try to control the radiating polarization and pattern by utilizing the conducting-plates positively as a radiating conductor and by changing current distribution on the ground-planes. One end of the excitation element is excited at the left-upper corner of the GND 1 (feed point), and the other end is connected to the right-upper corner of the GND 1 through the reactance-switching circuit, Z. The phase and amplitude (especially phase) of the current flowing from the element onto the GND 1 must depend considerably on the reactance value of Z. If the current flowing from the feed point onto the GND 1 and that from the reactance-switching circuit, Z, are almost in phase, z-component current becomes the dominant current mode for radiation. On the other hand, y-component current is dominant for radiation when those phases are different approximately by 180 degrees. Consequently, it is considered that we can control the polarization and pattern of the radiation field by appropriately choosing the reactance value of Z. It is assumed hereafter that the circuit Z has no resistance component, i.e., Z=jX.

3. Numerical and Experimental Results Figure 2 shows the correlation coefficient (marks •) versus "Arg(Z)" that denotes the argument of Z in the 50-ohms Smith chart. For example, Arg(Z)=0°, 90°, and 180° correspond to Z=j∞, j50, and j0 in ohms, respectively. The correlation coefficient means that between the radiation pattern for each Arg(Z) and that for Arg(Z)=0°. It is found that the radiation

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patterns for Arg(Z)=0° and for Arg(Z)=60° are considerably different from each other, because the correlation coefficient between them is approximately 0.2. It is noted here that the correlation coefficients are calculated by employing the complex radiation E-field in the X-Z and Y-Z planes, and the arrival wave condition is assumed that the cross polarization ratio is XPR=0-dB and the arrival wave come uniformly from any direction. Figure 2 also shows the polarization power ratio in X-Z plane for each Arg(Z), indicated with marks △, defined by

$$P_\theta / P_\phi = \int_0^{2\pi} |E_\theta|^2 d\theta \Big/ \int_0^{2\pi} |E_\phi|^2 d\theta \, .$$

From this result, it is found that the low correlation-coefficient between Arg(Z)=0° and 60° is mainly caused by the fact that the main polarization alternates in X-Z plane.

Figures 3 and 4 show the calculated and measured results of the radiation patterns for Arg(Z)=0° and 60°, respectively. The radiation *patterns* of each polarization component in X-Z plane are almost same between the two Arg(Z)'s, but the polarization ratio is drastically changed. On the other hand, in Y-Z plane, although the main polarization component of the radiation field does not alternate, its *pattern* is considerably changed. These radiation patterns are probably produced by the fact that z-directed current components is a dominant current mode when Arg(Z)=0°, while y components become a dominant current mode when Arg(Z)=60°.

In order to clarify the operating principle of the proposed antenna, we have calculated current distributions on the GND 1 and 2. Figure 5(i) shows the z-component current distributions for Arg(Z)=0° where (a) and (b) show the amplitude and phase distributions, respectively. When Arg(Z)=0°, the z-component currents are almost in phase. Therefore, the radiation pattern for Arg(Z)=0° become a z-directed dipole-like pattern, as shown in Fig. 3. On the other hand, the current distributions for Arg(Z)=60° are shown in Fig. 5(ii). In this case, the amplitude of the z-component currents flowing on the right-side of ground-planes and on the left-side are almost same each other, but their phases are different approximately by 180° each other. Therefore, the radiation field intensity due to z-component currents degrades, and y-component currents mainly contribute to the radiation field. Owing to this fact, the radiation pattern for Arg(Z)=60° becomes as shown in Fig. 4

Figure 6 shows the input impedance characteristics when Arg(Z)=0° and 60°. In this case, the characteristic of VSWR < 3 is obtained for both Arg(Z)'s. Noted here that inserting a matching-circuit whose impedance is switched for each Arg(Z) into the feed-point, mismatch-loss will be able to be reduced.

4. Conclusion

We have proposed a novel type of diversity antenna construction for compact mobile phones. The validity of the proposed diversity antenna construction has been demonstrated numerically and experimentally. Our next important works are to establish an optimum design theory and to investigate the performance in talking and brawzing situations.

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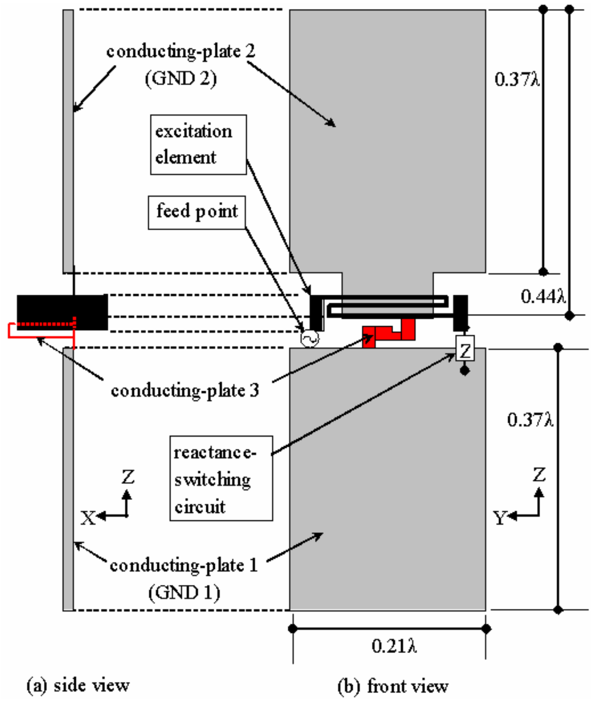


Fig. 1. Geometry of the antenna.

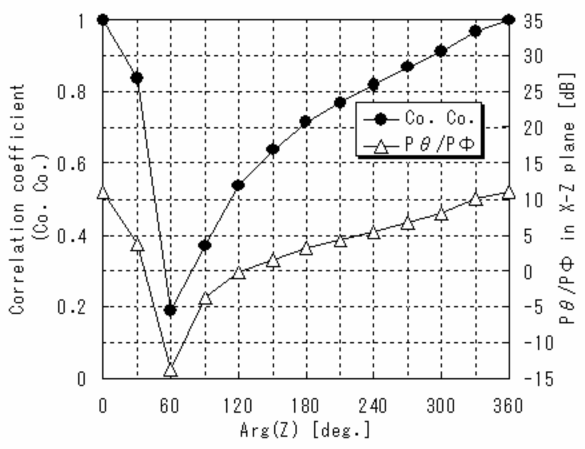


Fig.2. Correlation coefficient and polarization power ratio versus Arg(Z).

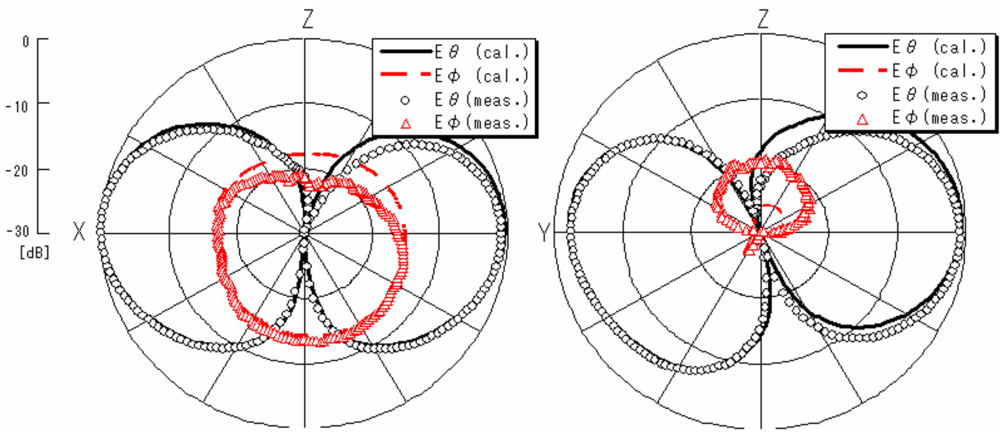


Fig. 3. Radiation pattern for Arg(Z)=0°. The left is in X-Z plane and the right is in Y-Z plane.

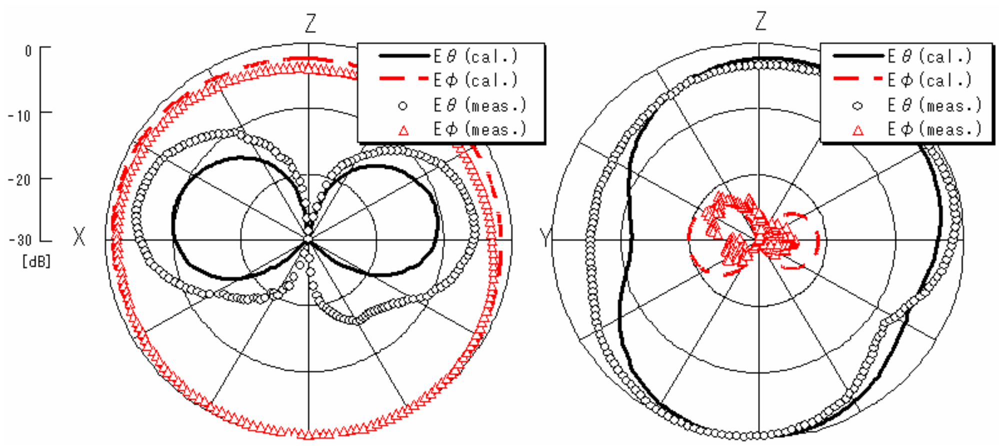
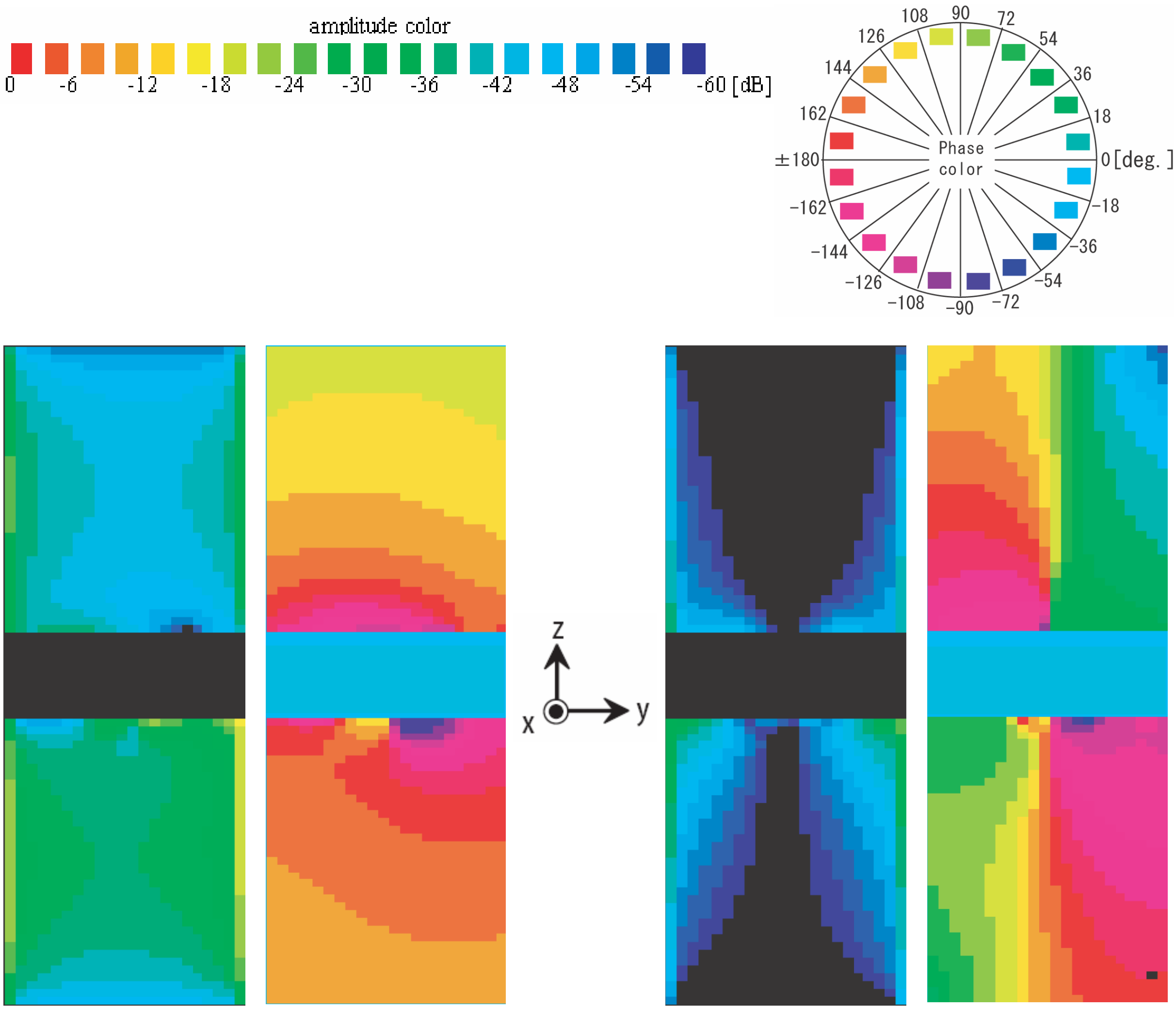


Fig. 4. Radiation pattern for Arg(Z)=60°. The left is in X-Z plane and the right is in Y-Z plane.



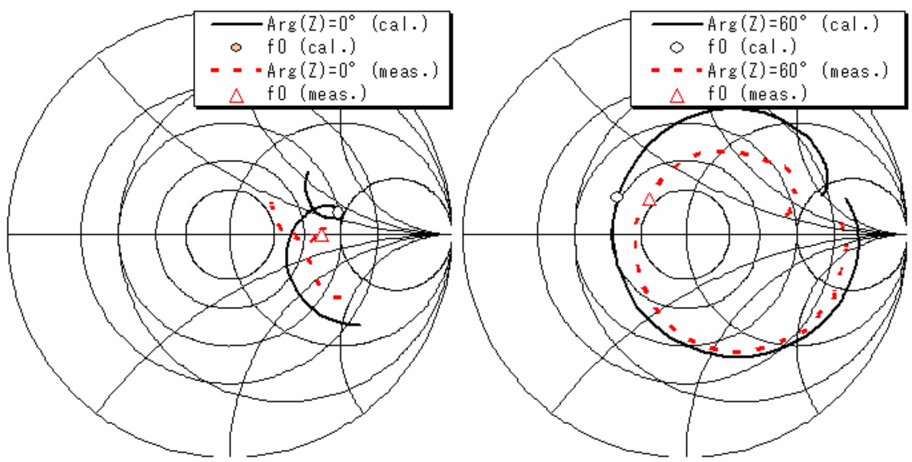
(a) Amplitude. (b) Phase.

(i) Arg(Z)=0°.

(a) Amplitude. (b) Phase.

(ii) Arg(Z)=60°.

Fig. 5. Z-component current distributions.



(a) Arg(Z)=0°. (b) Arg(Z)=60°.

Fig. 6. Input impedance characteristics. The normalized impedance is 50-Ω. The circles which are constant of VSWR denote VSWR=1.5, 2, 3, and 5, respectively. "f0" denotes the design frequency.