Unbalanced Fed Dipole Antenna Mounted on Ground Plane with L-shaped Parasitic Elements for Mobile Handsets

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1. Introduction

With the rapid development of cellular communication, various types of antennas for mobile handsets have been extensively proposed in recent years. If a large current flows on a ground plane on which a mobile handset antenna is arranged, the ground plane as well as the antenna element behave as radiating elements. Thus, degradation of the antenna characteristics occurs when the ground plane is held by a human hand. Using a balance-fed antenna is an effective way of reducing the current flowing on the ground plane and preventing the degradation of the antenna characteristics for the case when the antenna is operated near the human hand or head. For this purpose, various kinds of balance-fed antennas for mobile handsets have been proposed [2], [3]. In order to use a balance-fed antenna, the balun, which is a balanced to unbalanced transformer, needs to be inserted in series with the antenna and the feedline. However, the balun has an insertion loss that leads to the degradation of the antenna efficiency. It is reported that an unbalance-fed dipole antenna mounted on a ground plane can achieve characteristics equivalent to a balance-fed antenna without using the balun [4], [5].

In this paper, an unbalance-fed dipole antenna mounted on a ground plane with L-shaped parasitic elements for the mobile handsets is proposed. It is shown that the current flowing on the ground plane is sufficiently reduced by the use of the parasitic elements. It is also confirmed that the radiation efficiency of the antenna located near a human phantom has improved due to the suppression of the leakage current on the ground plane.

2. Antenna Structure

Figure 1 shows the configuration of the proposed antenna. A symmetrical dipole antenna is mounted on the ground plane. Structural parameters are designed such that the antenna operates at 2.0GHz. One of the radiating elements is excited by the voltage source connected in series with the radiating element and the ground plane, and the other element is in direct contact with the ground plane. In order to realize matching at the operating frequency, shorting pins are used as a matching section. The structure of the antenna is symmetric except for a feeding point. L-shaped parasitic elements are mounted on both sides of the ground plane in order to reduce the current flowing on the ground plane. The total length of the parasitic elements is chosen to be 38mm, which corresponds to a quarter-wavelength at the operating frequency of 2.0GHz.

3. Fundamental Characteristics of The Antenna

Fundamental characteristics of the proposed antenna are analyzed and measured. Numerical evaluation of the antenna performance is carried out using the electromagnetic simulator SEMCAD based on the FDTD method [6].

Figure 2 shows the frequency response of the reflection coefficients. Measured results for the case with parasitic elements are also indicated in this figure. The frequency response of reflection coefficients was acquired by analysis and is in good agreement with the response that was acquired experimentally. It is confirmed that the reflection coefficients are less than -10 dB at the operating frequency.

Figure 3 shows the radiation patterns of the proposed antenna. Solid and broken lines denote co-polarization and cross-polarization components, respectively. In this figure, the results are shown in terms of isotropic gain. The calculated results coincide well with the measured one, from which the validity of the FDTD analysis can be confirmed.

Figure 4 shows current density distribution on the ground plane obtained by FDTD analysis. The results both with and without parasitic elements are shown in this figure. Note that the results are normalized by the maximum value of the current amplitude. It can be observed that the current density at the bottom half of the image, which may be closely aligned with the human hand, is sufficiently reduced by connecting the parasitic elements to the ground plane. It is confirmed that the parasitic elements having a length equal to a quarter-wavelength are effective in the reduction of the leakage current on the ground plane.

4. Evaluation of The Radiation Efficiency

In order to demonstrate the effectiveness of the reduction of the leakage current on the ground plane due to the parasitic elements, the radiation efficiency is evaluated using the FDTD analysis for the case when the antenna is operated in the vicinity of the human phantom.

Two types of model consisting of a human phantom and the proposed antenna are assumed in the FDTD analysis. In the first model, a simple shaped phantom imitating the human hand is employed as shown in Figure 5(a). There are 0.5mm gaps between the sides of the ground plane and the phantom. The phantom does not touch the antenna. In the following discussion, this model is referred to as a simple-phantom model. In the second model, a phantom whose shape is very similar to the human hand is employed as shown in Figure 5(b). As was the case in the first model, the phantom does not touch the antenna. This model is referred to as a real-phantom model. For both models, the relative permittivity and the conductivity are chosen to be 40 and 1.4 S/m, respectively.

The radiation efficiency is calculated using the isotropic gain obtained by the FDTD analysis of the above-mentioned models. The radiation efficiency is calculated using the following equations [7].

$$\eta_{rad} = \frac{\Delta\theta}{2}\sum_{i=1}^{M}\left\{F(\theta_{i-1}) + F(\theta_i)\right\} \tag{1}$$

$$F(\theta_i) = \frac{\Delta\phi}{2}\sum_{j=1}^{N}\left\{G(\theta_i,\phi_{j-1}) + G(\theta_i,\phi_j)\right\}\sin\theta \tag{2}$$

$\Delta\theta$ and $\Delta\phi$ are discrete intervals of direction θ and ϕ. M and N are the sample numbers in the θ and ϕ directions, respectively. Note that the relations of $M = 2\pi/\Delta\theta$ and $N = \pi / \Delta\phi$ are hold between these parameters. $G(\theta_i, \phi_j)$ indicates the isotropic gain at the i-th and j-th discrete point in the θ and ϕ directions, respectively. The isotropic gain obtained by the FDTD analysis is assigned to the above equations (1) and (2) in order to evaluate the radiation efficiency.

In both models, the reference value for Z ($z = 0$) is the lower edge of the ground plane. For the simple-phantom model, Z_p is the hand's z-position with respect to the lower edge of the ground plane. For the real-phantom model, Z_p is the position of the little finger with respect to the lower edge of the ground plane. The radiation efficiency is also evaluated for the models consisting of the above-mentioned phantoms and a monopole antenna whose geometry is shown in Figure 6. Calculated radiation efficiencies are shown in Figure 7. In both models, the radiation efficiency of the antenna with parasitic elements is improved compared to the case without the parasitic elements. For the simple-phantom model, this is especially true when the phantom is located in the lower part of the ground plane.

5. Conclusion

In this paper, an unbalance-fed dipole antenna mounted on a ground plane with L-shaped parasitic elements for mobile handsets has been proposed. Fundamental characteristics of the antenna have been evaluated for the case when the antenna is closely aligned with a human phantom model. It is confirmed that the current at the lower end of the ground plane is sufficiently reduced by employing the parasitic element. It is also confirmed that the radiation efficiency of the antenna located near a human phantom is successfully improved due to the reduction of the leakage current on the ground plane.

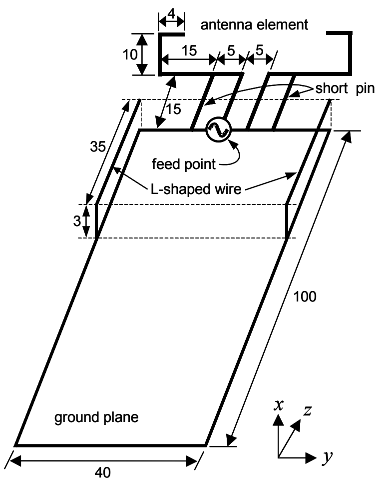

Figure 1. Antenna structure.

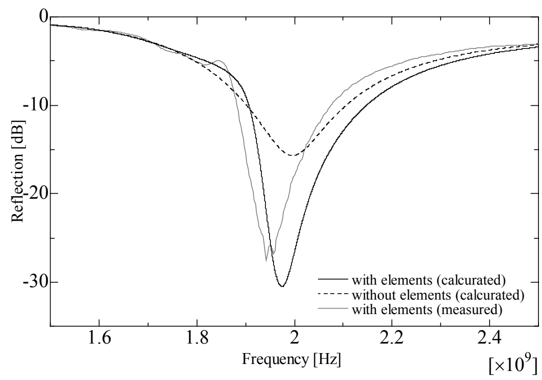

Figure 2. Frequency response of reflection coefficients.

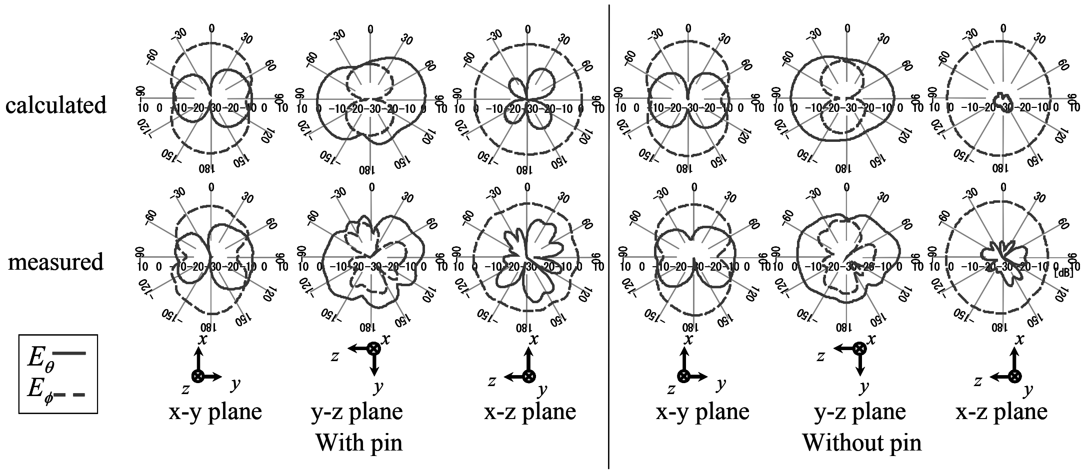

Figure 3. Calculated and measured radiation patterns at 2.0GHz.

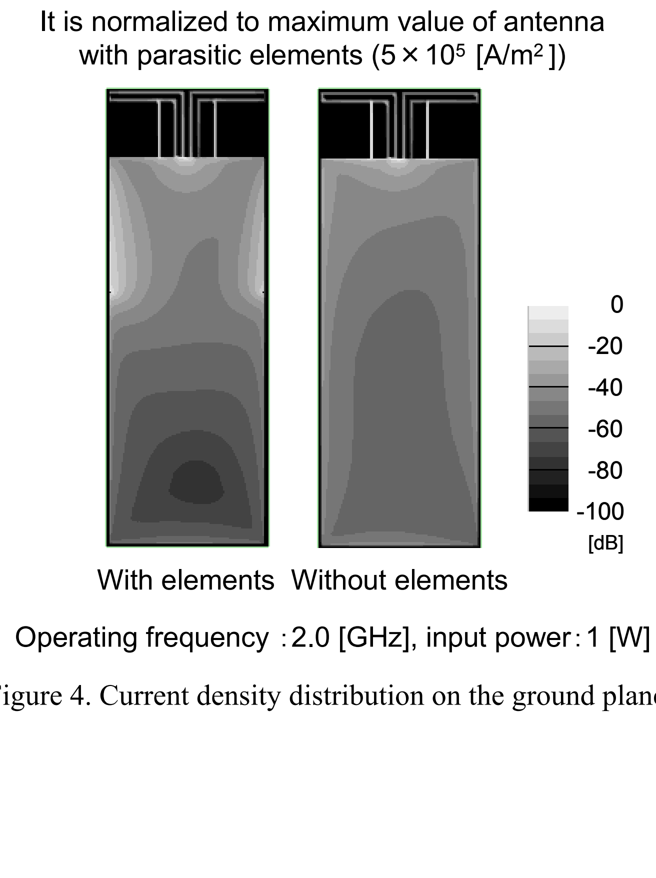

Figure 4. Current density distribution on the ground plane.

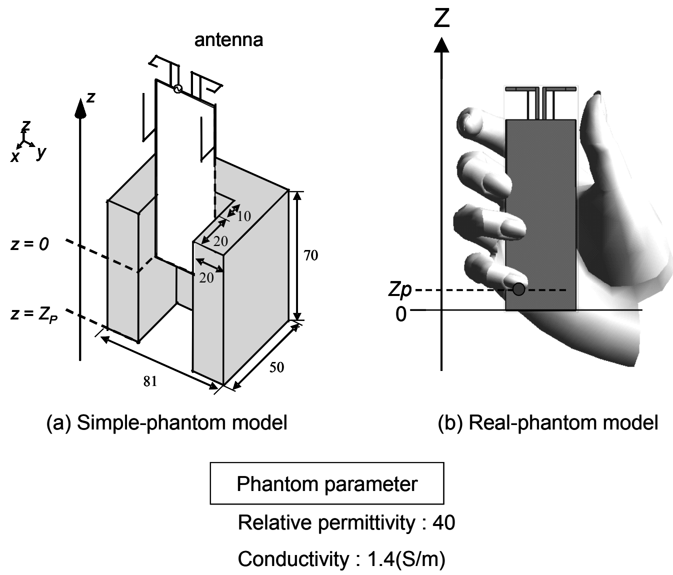

Figure 5: Models for radiation efficiency evaluation.

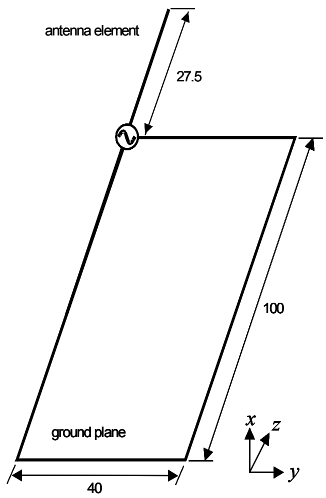

Figure 6: Monopole antenna.

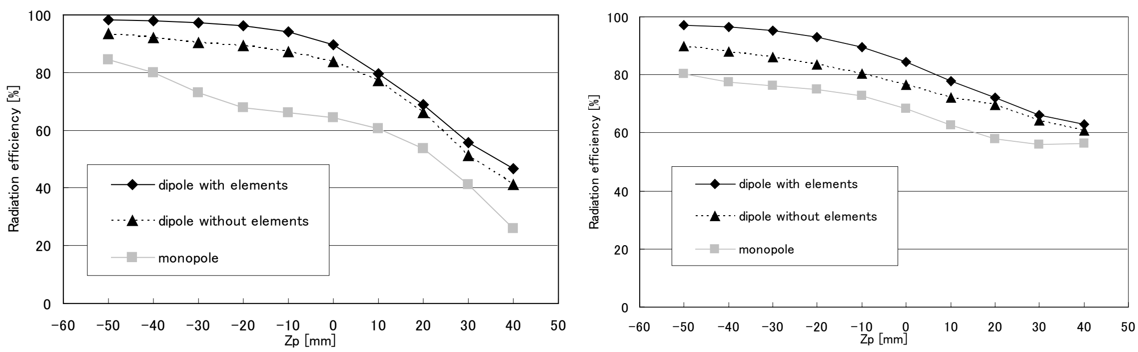

Figure 7. Calculated radiation efficiency.

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