Antenna Efficiency Characteristics for Capacitor-loaded Microstrip Antenna on a Lossy Small Metal Housing

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1. Introduction

Recently, directional antenna for a portable telephone terminal is proposed that does not harm or affect a human being [1]. This type of antenna provides relatively high gain even when used near a person's body, if the main direction of the pattern is aimed away from the body. Unfortunately, inverted-F antennas, which are mainly used for built-in antennas in commercial portable telephone terminals, have an omnidirectional pattern, and its gain is degraded by a person's body. It has been reported that setting a microstriop antenna on the outside of a small housing achieves a directional pattern and suppresses the spilt current on the housing [2]. However, such antennas are too large to fit in small portable telephones commonly used today.

This paper describes a technique for miniaturizing a microstrip antenna by using capacitance loading and analytically demonstrates that a microstrip antenna the same size as the inverted-F antenna provides high gain when put in a lossy small metal housing, i.e. an actual portable telephone terminal.

2. Miniaturizing technique by capacitance loading

The miniaturization method is to load a capacitor on the radiation edge of $\lambda/4$ microstrip antenna. It is considered that the loaded capacitance cancels reactance of the shorten radiation element. However, this often leads to problems in antenna efficiency. Therefore, the model of an antenna on the ground plane (as shown in Fig. 1(a)) is used to investigate the loss only of just the antenna element. A transmission line model [3], as shown in Fig. 1(b), is employed to analyze, for its simple concept and easiness to load capacitance. Thus, it can be easily used to examine loaded capacitance and antenna efficiency. From this circuit, input admittance is represented by the following expression:

$$Y_{in}=Y_0\frac{(Y_a+Y_c)+jY_0\tan\beta L_2}{Y_0+J(Y_a+Y_c)\tan\beta L_2}-jY_0\frac{1}{\tan\beta L_1} \qquad (1)$$

In this equation, β=phase constant. The capacitor admittance (Y_c) is determined as functions of the lengths L1 and L2 for antenna width $W=0.125\lambda_0$, height $h=0.025\lambda_0$ and input admittance to 0.02S in equation (1).

Figure 2 shows the relation between the antenna length and the capacitance, where the loss of a capacitor is equal to zero in the calculation. Calculation results in good agreement with experimental results in consideration of the capacitor loss in the experiment. Since input energy is consumed at real part of radiation and capacitor admittance, antenna efficiency can be expressed as

$$\eta=\frac{G_a}{G_a+G_c}, \qquad (2)$$

where G_a= real part of Y_a, G_c = real part of Y_c.

Figure 3 shows the relation between Q factor of the loaded capacitor to antenna efficiency (where $L=0.125\lambda_0$, C=1.25pF.). From this figure, the efficiency of the antenna loaded with a capacitor is above -0.5dB if the Q factor of the capacitor is more than 150. From Fig. 2, it is shown that experimental capacitance is 1pF when antenna length is equal to $0.125\lambda_0$. The Q factor of the capacitor is measured at about 150. Therefore, Q is set to 150 at the time antenna efficiency on the housing is calculated by wire grid model in next section.

3. Characteristic on lossy metal housing

This section examines antenna efficiency when the antenna is set on a lossy metal housing. The antenna structures are shown in Fig. 4 and the wire grid models are shown in Fig. 5. The volume of a capacitor loaded $\lambda/4$ microstrip antenna and inverted-F antenna are the same. The moment method is used in the antenna efficiency calculation.

After the antenna efficiency (where $L=0.125\lambda_0$, no loss on metal housing.) is calculated, it is compared with the result obtained from the antenna on the ground plane (Fig. 1) as shown in Table 1. The difference of each calculation is relatively small. Therefore, even if an antenna is built on a housing, it seems that the antenna efficiency to be high as long as Q of capacitor factor is above 150.

Figure 6 shows radiation patterns when there is no loss from the small metal housing. As mentioned in the introduction, the radiation pattern of the microstrip antenna is uni-directional. The radiation pattern of the inverted-F antenna, however, is omnidirectional.

The calculated results of antenna efficiency are shown in Fig. 7 for when antennas are set on lossy metal housings. When conductivity is low, the efficiency of the inverted-F antenna is lower than that of the capacitor loaded $\lambda/4$ microstrip antenna. This indicates that spilt current of inverted-F antenna is greater than that of the capacitor loaded $\lambda/4$ microstrip antenna because loss is only on the metal housing in the case of inverted-F antenna.

Thus, the capacitor loaded $\lambda/4$ microstrip antenna can be obtained higher efficiency when the antenna is set on a lossy metal housing of conductivity $\sigma < 600$ (S/m) than the inverted-F antenna.

4. Conclusion

This paper shows the method to miniaturize $\lambda/4$ microstrip antenna. To miniaturize the antenna, a capacitor is loaded on the radiation edge of $\lambda/4$ microstrip antenna. This provides high efficiency if the capacitor has a high Q factor (above 150). The capacitor loaded λ/4 microstrip antenna is more efficient than the inverted-F antenna if they are the same size and are both housed on a lossy metal housing.

References
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[2]S.Hagiwara, K.Tsunekawa, "Analysis of Housing Current Properties by Planar Antenna Attached on a Small Metal Housing", Proceeding of the 1995 IEICE General Conference, B-113 (Sep.,1995)
[3]I.J.Bahl, P.Bhartia, "Microstrip Antenna", Artech House, p31-55

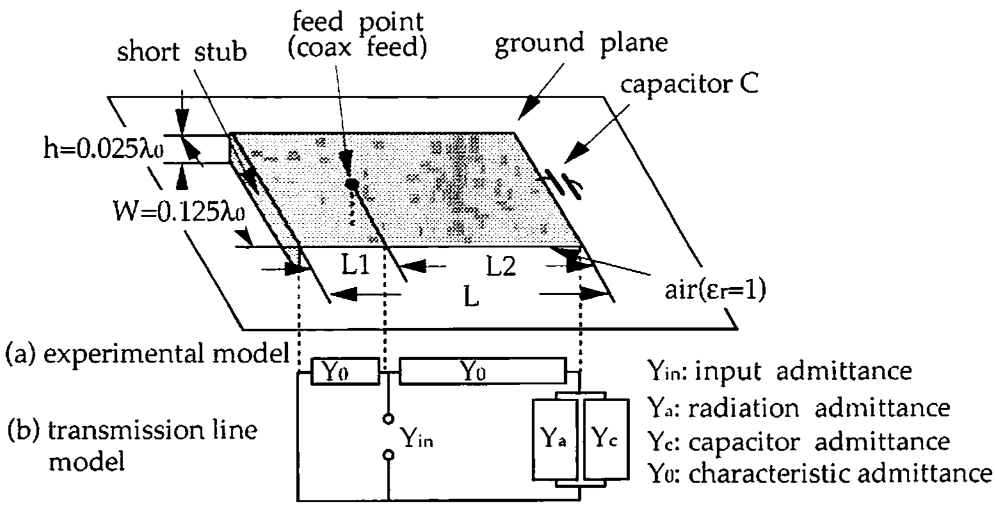


Fig. 1 Capacitor loaded microstrip antenna and its transmission line model

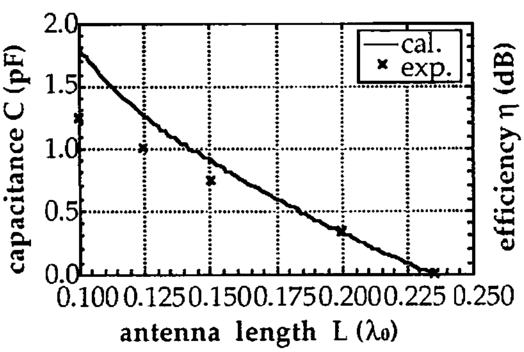


Fig. 2 Antenna length vs. loaded capacitance

(λ0: resonant wevelength)

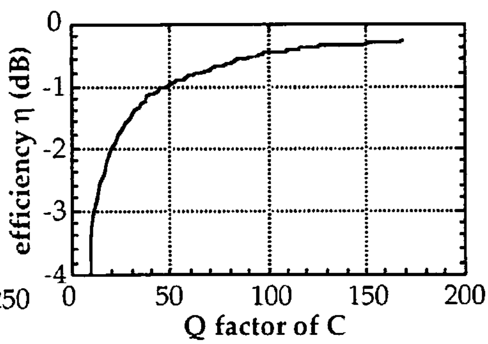
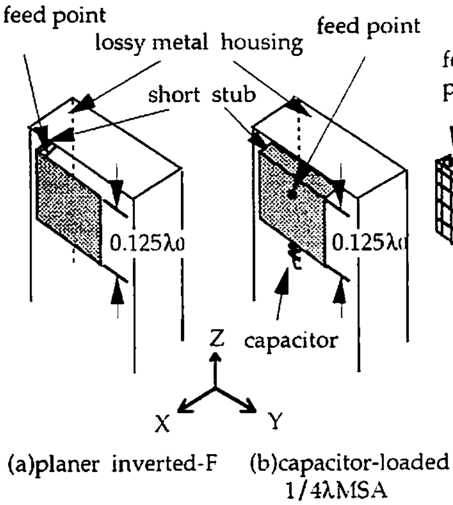


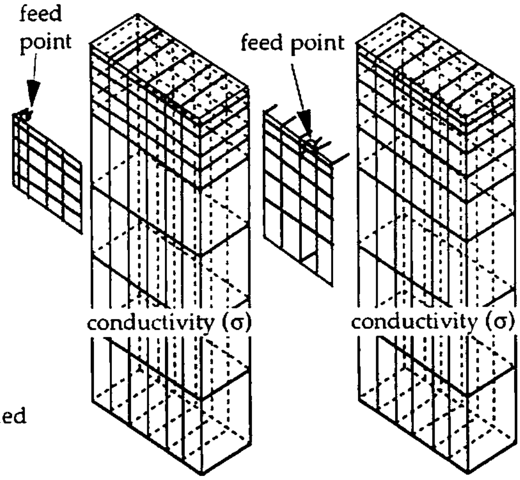
Fig. 3 Q factor vs. antenna efficiency

(L=0.125λ0,C=1.25pF)



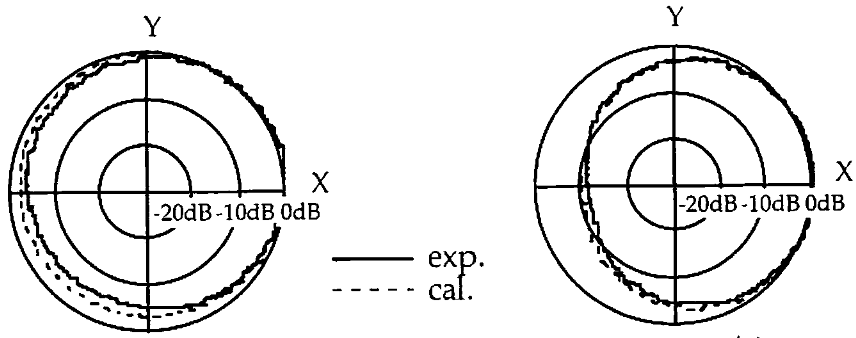
(metal housing: $0.65\lambda_0 \times 0.20\lambda_0 \times 0.09\lambda_0$
λ0: resonant wevelength)

Fig. 4 Antenna structure on a housing



(a)planer inverted-F (b)capacitor-loaded 1/4λMSA

Fig. 5 Wire grid model



(a) planer inverted-F (b)capacitor-loaded 1/4λMSA

Fig. 6 Radiation pattern

Table 1. Loaded capacitance and antenna efficiency

($L=0.125\lambda_0$)

	on a ground plane	on a housing
C(pF)	1.25	0.70
η(dB)	-0.4	-0.7

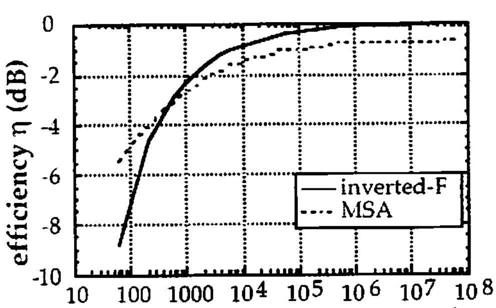


Fig. 7 Conductivity vs. antenna efficiency