CORRELATION COEFFICIENTS OF DIVERSITY ANTENNAS ON A SMALL METAL BODY

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INTRODUCTION

In mobile communication systems, diversity reception is one of significant and effective techniques to increase system capacity, since it mitigates multipath fading and achieves efficient spectrum utilization. In order to construct portable telephones for such systems, small diversity antennas which provide high gain and low correlation coefficients must be developed. However, the conventional space-diversity theory(1) predicts that it is impossible to provide low correlation coefficients with little antenna separation. In studies in which the mutual coupling between the antenna elements(2) has been considered, diversity antennas with little separation or on a small metal body have not been reported.

This paper presents a numerical analysis of the relation between antenna separation and correlation coefficients. When diversity antennas are mounted on a small metal body (about 0.5×0.1×0.1 wavelengths), each mutual couplings among antenna elements and metal body are considered. It was found that even 0.1-wavelength antenna separation yields a sufficiently low correlation coefficient of less than 0.1. An experiment was also conducted whose results were in good agreement with the numerical analysis.

FORMULATION OF CORRELATION COEFFICIENT

The diversity antennas considered here are constructed of two half-wave dipole antennas mounted on the small metal body, as shown in Fig. 1. The correlation coefficients of this model are discussed in terms of the effects of the three parts: Elements #1,#2 and the metal body. When Element #1 is fed, I_{11} is the surface current on itself, I_{12} is the induced current on the Element #2, which is terminated at resistance of 75Ω, and I_{1B} is the current on the metal body. By exchanging the conditions of the two elements, I_{22}, I_{21} and I_{2B} are defined in the same way. Each I value contains a spatial phase difference depend on its position. The I values are varied whether the mutual coupling is considered or not. E_1 and E_2, which are the fields when #1 is fed or #2 is fed, respectively, are given as

$$E_1(\theta,\Phi) = -j30k\frac{exp(-jkr)}{r}\int_v (I_{11}+I_{12}+1_{1B})dv \quad ....(1)$$

$$E_2(\theta,\Phi) = -j30k\frac{exp(-jkr)}{r}\int_v (I_{22}+I_{21}+I_{2B})dv \quad ....(2)$$

where, k is the free space wavenumber and r is the distance from the origin to observation point P. It is assumed that infinite number of waves are incoming at only $\theta = \pi/2$ and they have uniform distribution on Φ(3). The transmitting and receiving patterns of these antennas are the same according to the Reciprocity Theorem. Therefore, the correlation coefficient ρ is expressed(4) by

$$\rho = \frac{\left| \int_0^{2\pi} E_1^*(\pi/2,\Phi)E_2(\pi/2,\Phi)d\Phi \right|^2}{\int_0^{2\pi} E_1^*(\pi/2,\Phi)E_1(\pi/2,\Phi)d\Phi \int_0^{2\pi} E_2^*(\pi/2,\Phi)E_2(\pi/2,\Phi)d\Phi} \quad ....(3)$$

*is the complex conjugate

By using these equations, the correlation coefficient ρ is calculated from the complex radiation patterns: E_1 and E_2.

PARALLEL DIPOLE ANTENNAS

Only two half-wave dipole antennas with separation l exist in free space, as shown in Fig. 2. The correlation characteristics related to the antenna separation are numerically investigated in two cases. One is the case in which mutual coupling between the elements is ignored, i.e., only I_{11} and I_{22} are present in Eqs. (1) and (2), respectively. In this case, each element has the same pattern of the single dipole in free space except for the spatial phase difference determined by its position. According to the conventional space-diversity theory, the correlation coefficients are simply calculated under these conditions and they follow $J_0^2(kl)$, where J_0 is the zeroth order Bessel function. The other case is that in which mutual coupling between the elements is considered, i.e., I_{11}, I_{12}, $I_{21}$and I_{22} remain in Eqs. (1) and (2). The mutual couplings are calculated by the Moment Method(5).

The results by using Eq. (3) are shown in Fig. 3. The correlation coefficients considering mutual coupling decrease rapidly with increasing antenna separation l than when it isn't considered. When the antenna separation is 0.1 wavelengths, the correlation coefficient considering mutual coupling is 0.22, although the conventional space-diversity theory predicts 0.82. Therefore, when only diversity antennas with small antenna separation exist in free space, the pattern distortion caused by mutual coupling between the elements produces the pattern diversity effect, thereby causing the correlation coefficient decrease.

TWO DIPOLE ANTENNAS ON THE METAL BODY

When this type of diversity antennas is mounted on a small metal body, the relations between the correlation coefficients and the antenna separations are examined in two cases, which are not to consider and to consider mutual coupling between the elements. However, in both cases, the mutual coupling between each element and the metal body is considered. In other words, in Eqs. (1) and (2), I_{11}, I_{1B}, I_{22}, and I_{2B} exist on first case, all currents exist on second case. This study also employed the Moment Method. The wire mesh model and its size are shown in Fig. 4.

The results are presented by Fig. 5. In considering the mutual couplings, the correlation coefficients of the diversity antennas on the small metal body decrease rapidly with increasing antenna separation l, and they are lower than that of the diversity antennas in free space. When the antenna separation is 0.1 wavelengths, the correlation coefficient with considering all mutual couplings is 0.05 and it without mutual coupling between the elements is 0.62, although this is lower than that calculated by the space-diversity theory. The mutual coupling among the elements and the metal body produces heavy pattern distortion, as shown in Fig.6. Thus, when diversity antennas are mounted on a small metal body, the excessive pattern distortion by mutual couplings among the elements and the metal body yields a great pattern diversity effect

The correlation coefficients decrease owing to the mutual couplings among Elements #1, #2 and the metal body, as shown in Table 1. The experimental result is presented in this table, too. The correlation coefficients of described diversity antennas, whose elements were sleeve dipole antennas mounted on a small metal body, are measured outdoors in suburban area of Yokosuka City. The measured correlation coefficient was 0.16. Taking into account the difficulty of measuring extremely low correlation coefficients, this is in relatively good agreement with the calculated results.

CONCLUSION

When the diversity antenna is constructed with two half-wave dipoles and they are mounted on a small metal body, the correlation coefficients with antenna separation were studied by considering the mutual coupling among the elements and the metal body. It was found that even 0.1-wavelength antenna separation yields a sufficiently low correlation coefficient of less than 0.1, which cannot be predicted by conventional space-diversity theory. It was assured by calculation that the mutual couplings play a major role in obtaining low correlation coefficients, and that the pattern diversity effect is dominant over the space diversity effect in the region of small antenna separation. The calculated results were in relatively good agreement with the experimental result.

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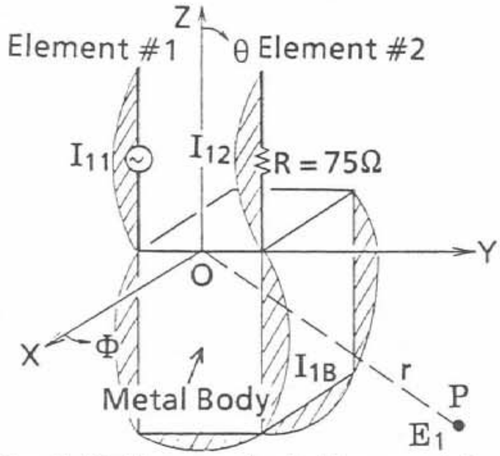

Fig. 1 Pattern calculation model of diversity antennas. (#1 is fed)

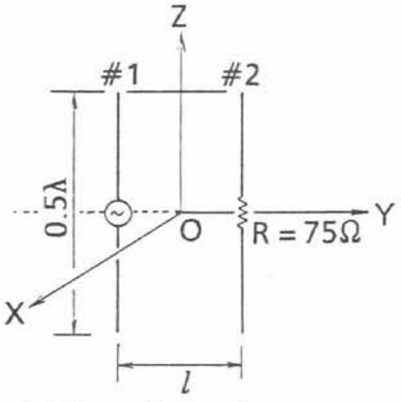

Fig. 2 Diversity antennas in free space. (#1 is fed, λ : wavelength)

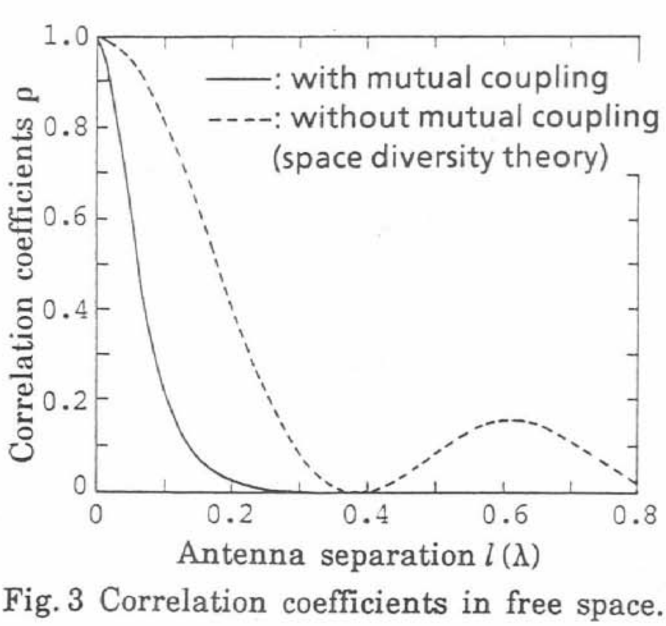

Fig. 3 Correlation coefficients in free space.

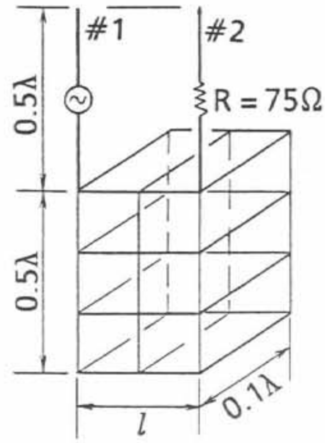

Fig. 4 Wire mesh model.
(#1 is fed)

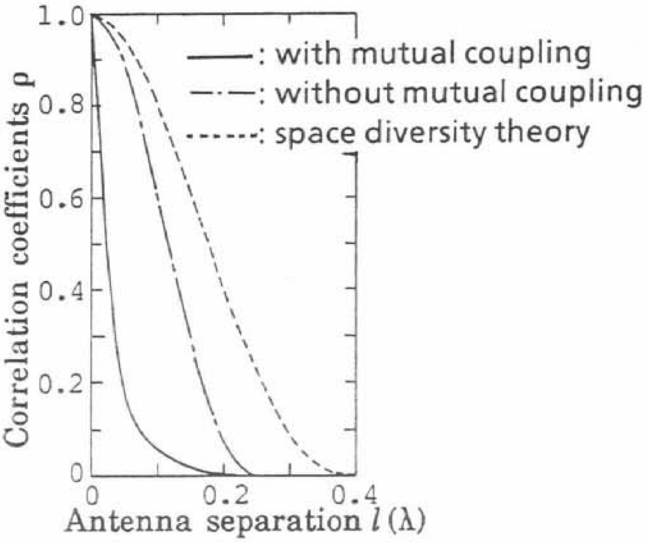

Fig. 5 Correlation coefficients on metal body.

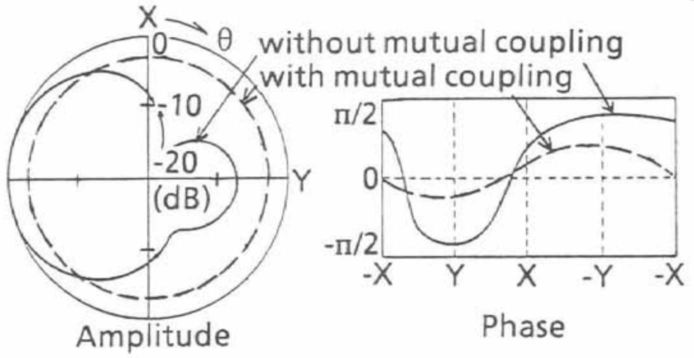

Fig. 6 Radiation patterns on metal body.
(Antenna separation l is 0.1 wavelengths)

Table 1 Summary of correlation coefficients.

· Numerical results

Mutual coupling	Diversity antennas	Existing currents	Correlation coefficients
Not considered	In free space	I_{11} , I_{22} (space diversity)	0.82
	On body	$I_{11}+I_{1B}$, $I_{22}+I_{2B}$	0.62
Considered	In free space	$I_{11}+I_{12}$, $I_{22}+I_{21}$	0.22
	On body	$I_{11}+I_{12}+I_{1B}$, $I_{22}+I_{21}+I_{2B}$	0.05

· Experimental result

Diversity antennas on metal body	0.16

(Antenna separation l is 0.1 wavelengths)