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PHYSICAL OPTICS ANALYSIS OF SCATTERING FROM A FINITE STRIP ARRAY ON A GROUNDED DIELECTRIC SLAB

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1. Introduction

Recently a variety of researchers have investigated the scattering from anisotropic surfaces [1][2]. Such anisotropic surfaces, for example the conducting strips on a grounded dielectric slab, can be used to realize ideal artificially soft and hard surfaces [3][4][5] and to control the radiation patterns.

These surfaces, as applied to practical engineering, are finite sized; the method for predicting scattering from the surface is necessary. We have applied Physical Optics (PO) in calculating radiation patterns of such an anisotropic surface, and asymptotic evaluation of surface integration in PO has already been discussed in [6]. In spite of these, the applicability of PO for this type of artificial surface is not fully confirmed.

The purpose of this paper is to study the scattering of a $\lambda/2$ dipole antenna over a finite strip array on a grounded dielectric slab. The applicability of PO for such an anisotropic surface is discussed. At the same time, the pattern control by the anisotropic ground plane is suggested. Considerable errors are expected for the closer dipole. PO is applicable for the dipoles in the distance of more than 0.5 wavelength away from the surface. In the observation plane where incident electric fields are perpendicular to the strips, larger errors are observed. This may be due to the excitation of surface waves[7][8].

2. Closed Form Reflection Coefficients and Calculation Methods

In reflection from isotropic surface, the polarization remains unchanged. For anisotropic surfaces, this is not true generally. The geometry chosen for the study is conducting strips on a grounded dielectric slab as is shown in Fig. 1. Plane wave incidence and no loss material in the slab are assumed. The reflected wave is expressed in the series of Floquet's mode. From a practical point of view for the soft and hard surfaces, $P<<\lambda$ is generally satisfied and only the lowest term is the propagating mode.

First, the closed form expressions for tangential components of the reflected electromagnetic fields (E_y, H_y, E_x, H_x) at the origin are summarized:

$$E_y = B_0, \quad H_y = D_0 \tag{1}$$

$$E_x = \frac{1}{\gamma^2 - k^2}(B_0 \gamma S_0 - \omega\mu_0\beta_0 D_0), \quad H_x = \frac{1}{\gamma^2 - k^2}(D_0 \gamma S_0 + \omega\varepsilon_0\beta_0 B_0) \tag{2}$$

where:

$$B_0 = \frac{a_3 \cdot b_1 - a_1 \cdot b_2 - a_5 \cdot b_1}{a_1 \cdot b_2 - a_2 \cdot b_1 + a_5 \cdot b_1} \cdot \mathcal{E}_y + \frac{2\tau \cdot cos\theta \cdot (\mu_r + \tau) \cdot b_2 \cdot \eta}{a_1 \cdot b_2 - a_2 \cdot b_1 + a_5 \cdot b_1} \cdot \mathcal{H}_y \tag{3}$$

$$D_0 = \frac{-2\tau \cdot cos\theta \cdot (\mu_r + \tau) \cdot b_2}{(a_1 \cdot b_2 - a_2 \cdot b_1 + a_5 \cdot b_1) \cdot \eta} \cdot \mathcal{E}_y + \frac{2(a_2 - a_5) - a_4 \cdot b_2 + b_1 \cdot (a_5 - a_2)}{a_1 \cdot b_2 - a_2 \cdot b_1 + a_5 \cdot b_1} \cdot \mathcal{H}_y \tag{4}$$

while *a's*, *b's*, k, γ, *So* and βo are the coefficients defined by the parameters of the geometry [9]. $\mathcal{E}_y$ and $\mathcal{H}_y$ are the tangential (y) components of incident fields.

The model chosen for the calculation is shown in Fig. 2. In PO, scattering from a finite size surface is calculated by the radiation integral of the equivalent currents *Ix*, *Iy*, *Mx* and *My* over the surface. To this end, the total electromagnetic fields at any point on the surface are derived in the sense of physical optics approximation (PO). The equivalent currents are given by $\boldsymbol{I} = \hat{n} \times \boldsymbol{H}$ and $\boldsymbol{M} = \boldsymbol{E} \times \hat{n}$, where $\boldsymbol{H}$ and $\boldsymbol{E}$ mean the total magnetic and electric fields, and $\hat{n}$ means the unit vector normal to the surface. Since $\hat{n} = \hat{z}$:

$$I_x = -(\mathcal{H}_y + H_y), \quad I_y = (\mathcal{H}_x + H_x) \tag{5}$$

$$M_x = (\mathcal{E}_y + E_y), \quad M_y = -(\mathcal{E}_x + E_x) \tag{6}$$

Integration of these equivalent currents over the actual surface gives the final results of scattering from the reflector.

$$\vec{A} = \frac{e^{-jkR}}{4\pi R}\int_s \vec{I} e^{jk\hat{r}\cdot r'} ds, \quad \vec{B} = \frac{e^{-jkR}}{4\pi R}\int_s \vec{M} e^{jk\hat{r}\cdot r'} ds \tag{7}$$

$$\vec{E}_s = -j\omega\left(\mu\vec{A} + \varepsilon\vec{B} \times \hat{r}\right) \times \hat{r} \times \hat{r} \tag{8}$$

3. Results of PO Calculation and Experiments

The accuracy of PO is evaluated by comparing the calculation and measurement for the model in Fig. 2. The periphery of a disk is covered with the absorber to suppress the possible radiation of surface waves within the dielectric slab. The distance between the center of the antenna and the reflector plane is varied from $d = 0\lambda$ to $d = 2.6\lambda$. Figure 3a and Fig. 3b show the radiation patterns in *x-z* ($\phi = 0°$) and *y-z* ($\phi = 90°$) planes, respectively. For the dipoles in the distance of more than 0.5λ, the measurement and the prediction is in good agreement. However as the distance becomes smaller than that, especially in the *x-z* plane, the discrepancy becomes notable. The patterns in the *y-z* plane are reasonably predicted even at $d = 0\lambda$. When the distance of d becomes to 0λ, the calculation and experiments are carried out by using a $\lambda/4$ monopole antenna on a 4λ diameter reflection disk. The difference of the accuracy in different observation planes is unique for anisotropic surface. The microscopic analysis such as local excitation of surface waves may be essential for the full explanation [10].

Another point of view from the comparison of Figs. 3a and 3b is that the null points are clearly shifted due to the anisotropic nature of the surface. It suggests that radiation patterns can be controlled by using the strips on a grounded dielectric slab.

As the high frequency technique, the PO surface integral can be reduced to two points contribution using diffraction coefficients. The Physical Optics diffraction coefficients were already derived for the calculation of conducting strips on a grounded dielectric slab in [6]. The calculated results using diffraction coefficients for the model of Fig. 2 when $d = 2.6\lambda$ are also included in Fig. 3a and Fig. 3b in dashed line.

4. Conclusion

The radiation patterns of antennas are affected by the conducting strips on a grounded dielectric slab. The validity of PO calculation for a dipole antenna using the analytical reflection coefficients for this anisotropic surface is verified by experiments. They are generally in good agreement for the distance between source and the surface larger than 0.5λ. The minimum spacing for the accuracy is dependent on the strip orientation and the observation plane. Surface wave excitation should be taken into account for enhancing the accuracy in future study.

References

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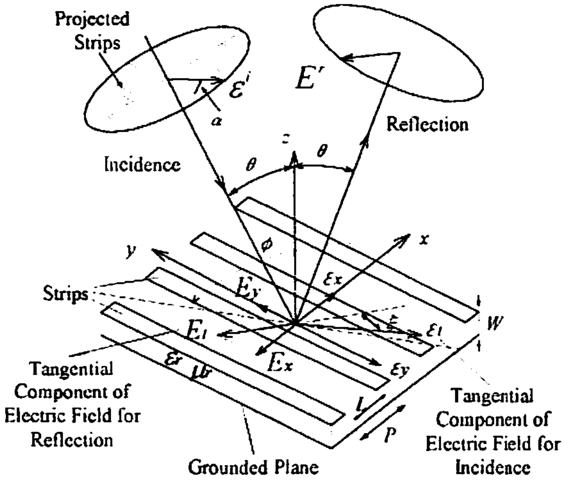

Fig. 1 Incident and reflected fields projected on the anisotropic surface

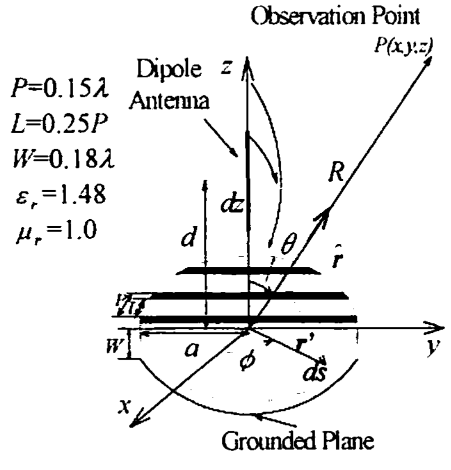

Fig. 2 A $\lambda/2$ vertical dipole antenna over the anisotropic surface

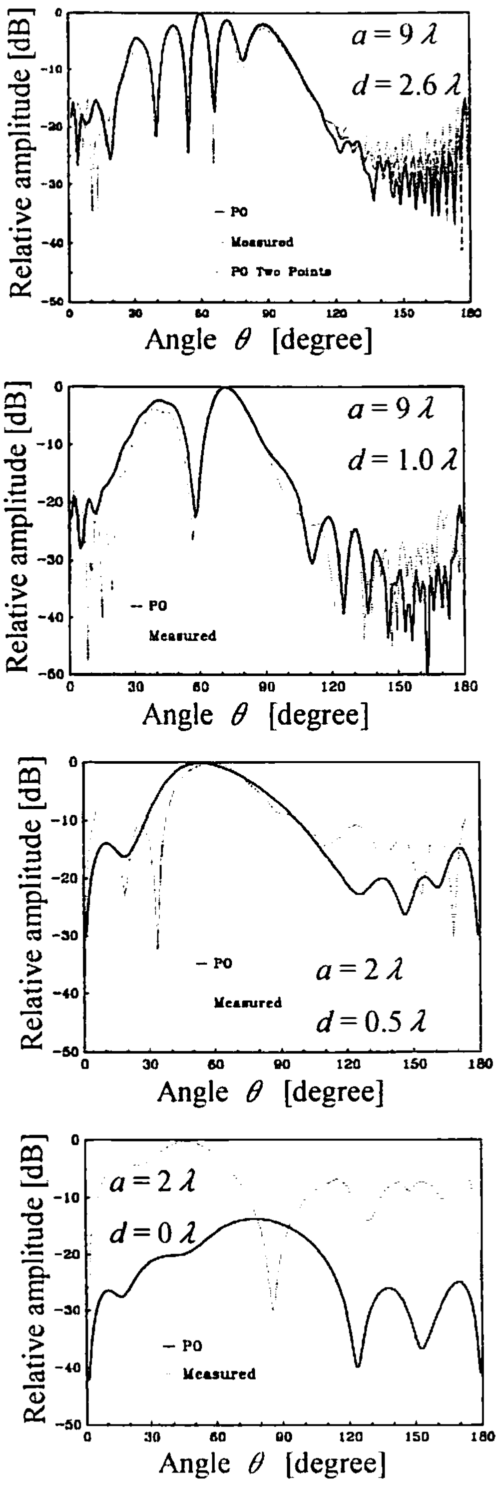

Fig. 3a radiationpatterns of x-z plane with different d and a

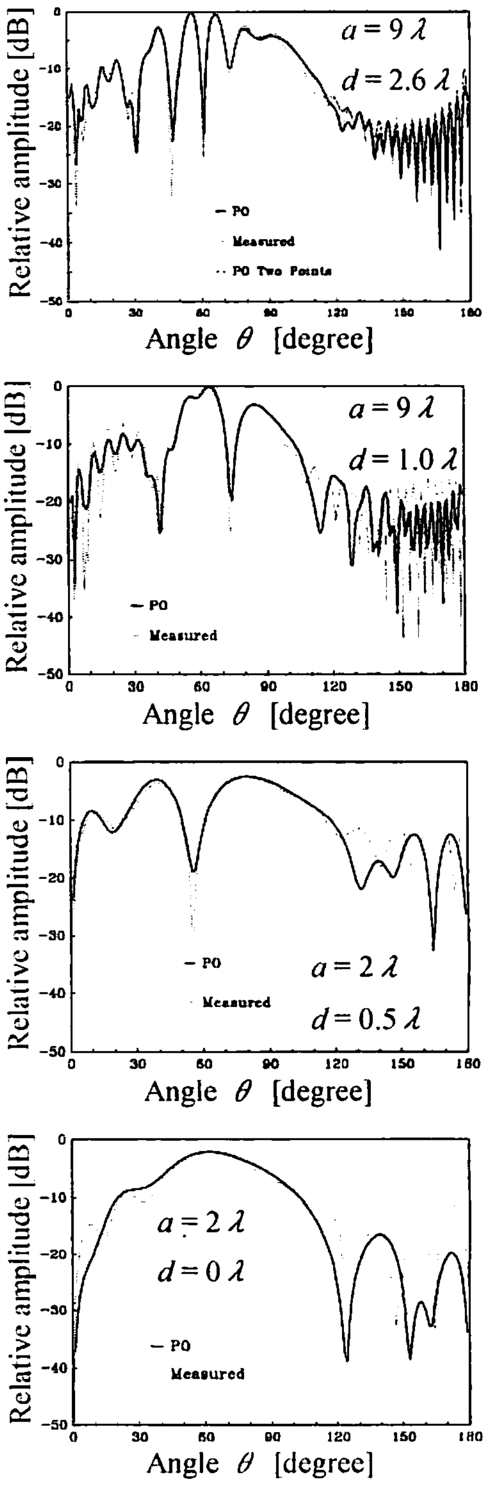

Fig. 3b Radiation patterns of y-z plane with different d and a