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Diffraction of waves by a conductive half-plane

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ABSTRACT

The scattering process of plane waves by a conductive half-plane is investigated. The scattered geometrical optics waves are obtained by subtracting the incident field from the total geometrical optics waves. The physical optics integral is constructed from the scattered geometrical optics fields. The diffracted waves are evaluated by the application of the edge point method to the physical optics integral. A correction field is added to the diffracted waves in order to satisfy the conductive boundary conditions on the surfaces of the half-plane. The uniform diffracted fields are evaluated and the resultant scattered waves are compared with the literature numerically.

1. Introduction

The wave diffraction problem by a half-plane is an important canonical problem that enables one to examine the scattering process of waves by complex geometries like the aircrafts and ships in the high-frequencies [1]. The exact solution of this problem was put forth by Sommerfeld in 1896 for a perfectly conducting half-screen [2]. However a perfectly conducting surface is an idealization and does not counter actual problems, which include lossy surfaces. Raman and Krishnan [3] extended the solution of Sommerfeld by multiplying the reflected scattered waves by a Fresnel coefficient that models the absorption rate of the scattering surface. It was experimentally confirmed that such a formulation is more suitable for the analysis of the diffraction phenomena by actual scatterers [4]. The lossy surfaces are generally named as metallic surfaces and are modeled by three groups of boundary conditions [5]. The first type of boundary condition models a dielectric coated perfectly conducting layer and only reflect waves with loss. This structure is called as an impedance surface in the literature. The second boundary condition is defined for a thin dielectric layer which reflects some portion of the incoming radiation and transmits the other part. Such a surface is named as resistive. The last boundary condition is introduced as the electromagnetic dual of a resistive surface. This type of scatterer is known as the conductive surface and only supports a magnetic surface current density. The scattering process of waves by a conductive half-plane was investigated by Senior with the method of Wiener-Hopf factorization [6]. However, we showed in our previous studies that the solutions of the impedance and resistive half-screen problems, which were obtained by the methods of Wiener-Hopf factorization and Sommerfeld-Maliuzhinets [7–9], were not correct, because the diffracted fields did not satisfy the related boundary conditions [10–13]. The main problem is in the structure of the diffracted wave, which can be expressed by

$$u_d = f(\phi)\frac{e^{-jk\rho}}{\sqrt{k\rho}} \tag{1}$$

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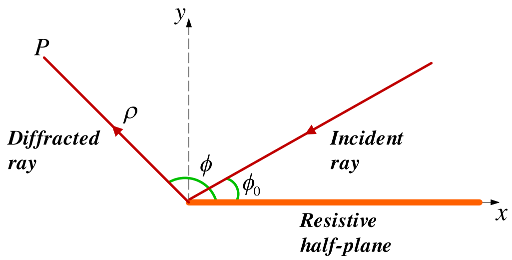

Fig. 1. Diffraction geometry of the conductive half-plane.

where k is the wavenumber [13]. The polar coordinates are expressed by (ρ,ϕ). The expression of the function f can be found in [5] for the conductive half-plane. The boundary conditions can be given by

$$\frac{\partial u_d}{\partial \phi}\Big|_{\phi=0} - \frac{\partial u_d}{\partial \phi}\Big|_{\phi=2\pi} = 0 \tag{2}$$

and

$$\frac{2}{jk\rho\eta}\frac{\partial u_d}{\partial \phi}\Big|_{\phi=0} = u_d|_{\phi=0} - u_d|_{\phi=2\pi} \tag{3}$$

for a resistive half-plane. u_d is the z polarized electric field intensity of the diffracted wave and the edge contour of the half-plane is located on the z axis. η is equal to $2R_mZ_0$ where R_m and Z_0 are the conductivity of the surface and impedance of the free space respectively. The equation

$$\frac{2}{jk\rho\eta}\frac{\partial f}{\partial \phi}\Big|_{\phi=0} = f(0) - f(2\pi) \tag{4}$$

can be obtained when Eq. (1) is used in Eq. (3). Eq. (4) has only one implication; *f must also be a function of ρ besides ϕ in order to satisfy* Eq. (4). This simple analysis shows that the solution, in the literature, is not exact.

The aim of this paper is to derive a solution of the diffraction problem of plane waves by a conductive half-plane that satisfies the related boundary condition. First of all, we will obtain the scattered geometrical optics (GO) waves by subtracting the incident wave from the total GO fields. By using the scattered GO field, the scattering integral of physical optics (PO) will be constructed. The edge diffracted fields will be derived from the edge point evaluation of the PO integral. We will add a suitable diffracted field to the evaluated waves in order to get a solution that will satisfy the conductive boundary conditions. The uniform expression of the total diffracted wave will be derived and compared with the solution, in the literature, numerically.

A time factor $e^{j\omega t}$ will be suppressed throughout the paper. ω is the angular frequency.

2. Theory

A conductive half-plane located at $x \in [0,\infty)$, $y = 0$ and $z \in (-\infty,\infty)$. It is illuminated by the incident wave

$$u_i = u_0 e^{jk\rho\cos(\phi-\phi_0)} \tag{5}$$

for u_i is the z component of the incident electric field intensity. u_0 is the complex amplitude. ϕ_0 shows the angle of incidence. Our aim is to determine the total diffracted fields when the incident field interacts with the half-screen. The total scattered wave can be obtained by summing the total diffracted and GO fields. The geometry of the problem is given in Fig. 1. P is the observation point.

The total scattered field can be written as

$$u_T(P) = u_i(P) + \frac{ke^{j\frac{\pi}{4}}}{\sqrt{2\pi}} \int_C u_i(Q)\, G(P,Q)\, dl' \tag{6}$$

for two dimensional problems according to PO [14]. C shows the integration contour and G is a suitable Green's function. Q is the integration point. In the classical PO theory, the Green's function is taken as the spherical wave factor for three dimensional problems, but this approach leads to incorrect diffracted field expressions. We obtained the exact diffracted waves for a perfectly conducting half-plane by evaluating a new Green's function with the modified theory of physical optics (MTPO) approach [15,16]. The integral, in Eq. (6), gives the scattered waves by the obstacle. Since the incident field is a GO wave, the relation

$$u_{TGO} = u_i + u_{SGO} \tag{7}$$