THE VALIDITY OF APPROXIMATING CURRENTS ON A RESISTIVE STRIP USING PHYSICAL OPTICS

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Introduction

Calculating the currents induced on an object when excited by an electromagnetic wave, usually involves approximate methods. Rarely do exact solutions exist. Physical Optics (PO) offers a simple approach to the problem at the expense of accuracy. Since PO is a local phenomenon, it does not take into account interactions between surfaces, diffraction from edges, tips, corners, etc. On the other hand, more accurate techniques require complicated computer solutions.

This paper investigates the validity of applying PO to find the currents induced on a resistive strip by an incident plane wave. Prior investigations did not consider PO as a viable method. Senior and Liepa obtained the currents induced in resistive strips by using the method of moments (MOM)[1]. More recently, Ray and Mittra used the spectral iterative technique to find the currents in such strips[2]. In these two studies the strip either had a uniform or a tapered resistivity. In this study currents on strips having various resistivities were computed using MOM and PO expressions. The results indicate that PO provides simple, accurate expressions for the current when the resistivity on the strip has a smooth taper with large values of resistance at the edges.

Problem Formulation

Figure 1 is a model of the problem. The resistive strip is 4λ wide and lies in the xy plane centered on the z axis. Although both E-polarized ($E_z = exp(-ik(xcos\phi_0 + ysin\phi_0))$) and H-polarized ($H_z = exp(-ik(xcos\phi_0 + ysin\phi_0))$) incident waves were investigated, only the E-polarized results are detailed here.

The boundary condition at the resistive surface for an E-polarized incident plane wave is given by[1]

$$E_z = J_z R \qquad \text{and} \qquad H_x^+ - H_x^- = -J_z$$

Plus and minus signs on H_x indicate upper and lower faces of the strip respectively. R is the resistivity of the strip in ohms. When R=0 the strip is perfectly conducting.

The integral equation for finding the current on a resistive strip resulting from an E-polarized incident field is

$$E_z^i(x) = RJ_z(x) + \frac{kz}{4} \int J_z(x') H_o^{(1)}(k|x - x'|) dx'$$

where $H_o^{(1)}$ is the zero order Hankel Function of the first kind and Z is the intrinsic impedance of free space. This equation was programmed and solved using MOM.

A much simpler method is to use the PO expressions for the current[3] given by

$$J_z(x) = \frac{2sin\phi_0}{Z + 2Rsin\phi_0} e^{-ikxcos\phi_0}$$

This equation provides an easy solution for the problem, but does not take into account edge diffraction nor interactions between surfaces. Thus, PO is appropriate in cases where edge diffractions and surface interactions can be ignored.

Comparison of MOM and PO Solutions

The MOM and PO solutions for surface fields are compared for various strip resistivities and angles of incidence. The surface field for E-polarization is given by $ZJ_z(x)$ and for H-polarization $J_x(x)/Z$. Figures 2 through 5 illustrate the comparison. Figure 2 shows the surface field induced on a perfectly conducting strip due to an E-polarized plane wave at normal incidence. Agreement between MOM and PO is good at the center of the strip and poor at the edges. Changing the angle of incidence from normal creates greater disparity between the solutions.

Figure 3 shows the surface fields induced on a resistive strip that has a uniform normalized resistance of $R_n = R/Z = 2$, where R is the strip resistivity and Z the intrinsic impedance of free space. PO and MOM have better agreement on a resistive strip, but PO still fails at the edges.

Figure 4b shows the surface fields on the strip with resistive edge loading. The strip is 4λ wide. The center of the strip is perfectly conducting and the outer ends $.5\lambda$ from either edge have a normalized resistivity, $R_n = 2$ (Figure 4a). Although the edges are loaded, there is an abrupt discontinuity in the resistivity of the strip. As a result, PO and MOM do not agree well.

Figures 5a,b, and c demonstrate the effects of a smooth resistive taper. Figure 5a shows the normalized resistive taper vs. distance along the strip. The corresponding surface fields induced by an E-polarized plane wave are shown in Figure 5b. Now, there is a remarkable agreement between PO and MOM solutions. Figure 5c shows the solution for an H-polarized plane wave. In both cases PO provides a reasonable alternative for finding the currents on a resistive strip.

Conclusion

Under two conditions PO offers an alternative to MOM when calculating the surface fields (or currents) on a resistive strip. However, there are restrictions: first, the resistivity at the edges must be very high and second, the resistive taper across the strip must be as smooth as possible.

References

1. T. B. A. Senior and V.V. Liepa, "Backscattering from Tapered Resistive Strips," IEEE Trans. AP, vol 32, no 7, July 1984, pp 751-754.
2. S. Ray and R. Mittra, "Scattering from Resistive Strips and from Metallic Strips with Resistive Edge Loading," IEEE 1983 AP-S Intl Sym Digest, pp 603-606.
3. T. B. A. Senior, "Scattering by Resistive Strips," Radio Science, vol 14, no 5, Sep-Oct 1979, pp 911-924.

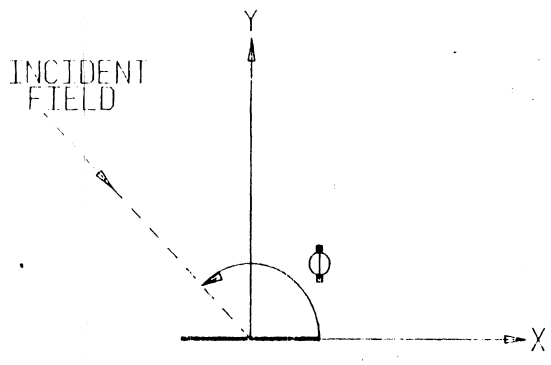

Figure 1. Geometry of the Problem

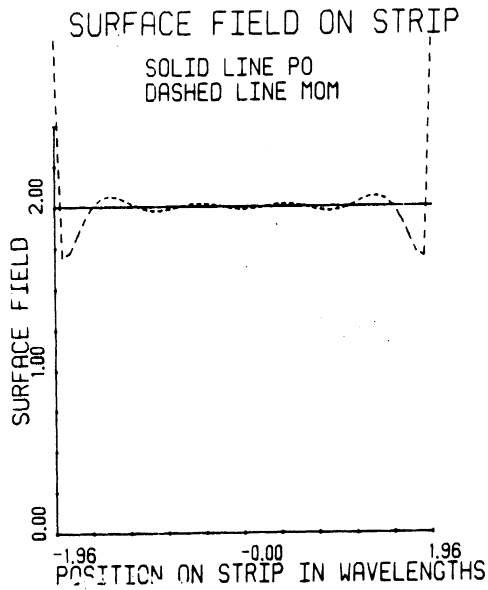

Figure 2. Surface Fields on a Perfectly Conducting Strip E-Polarization

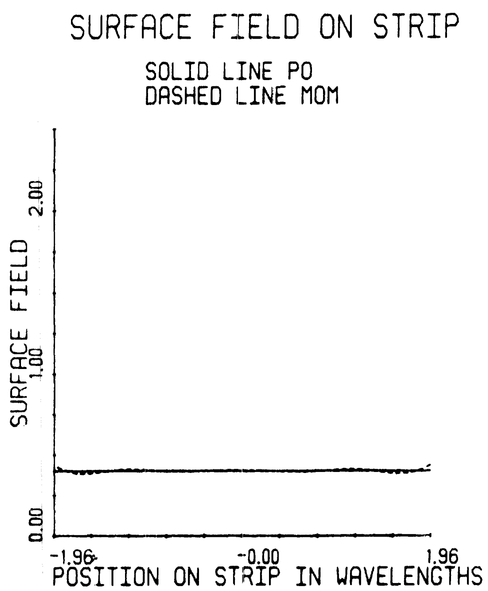

Figure 3. Surface Fields on a Resistive Strip ($R_n = 2$), E-polarization

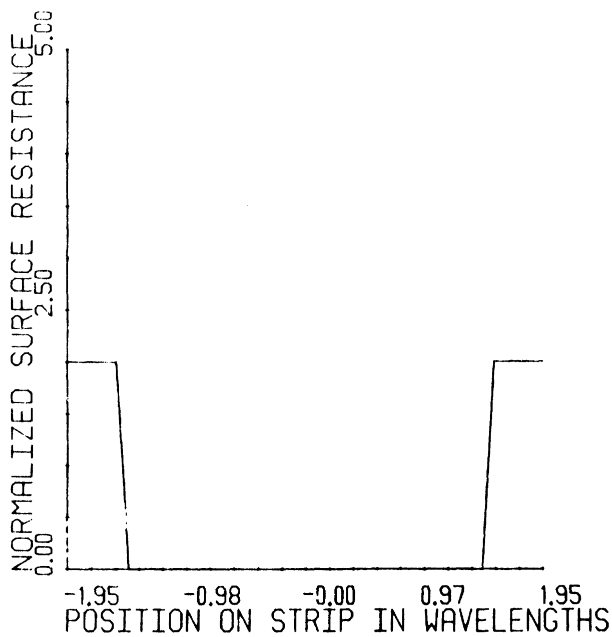

Figure 4a. Strip with Edge Loading

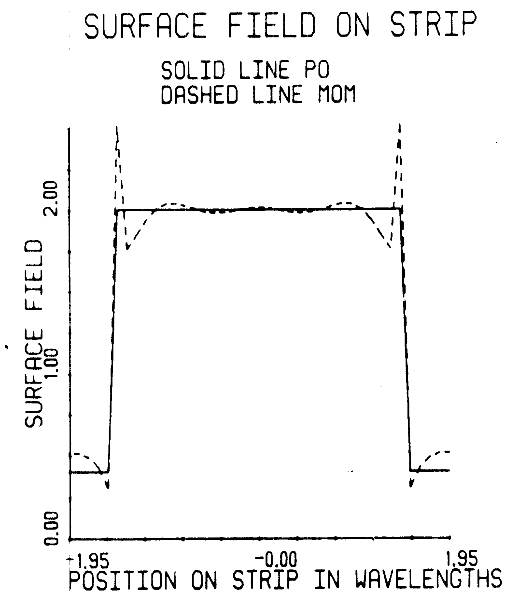

Figure 4b. Surface Field

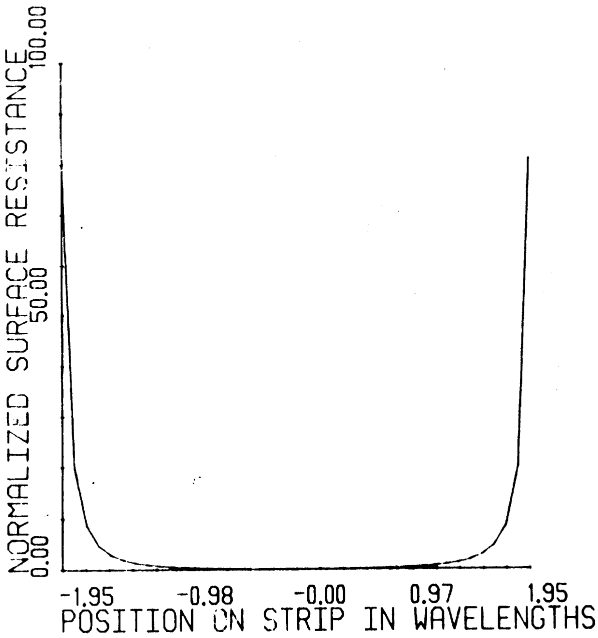

Figure 5a. Resistive Taper

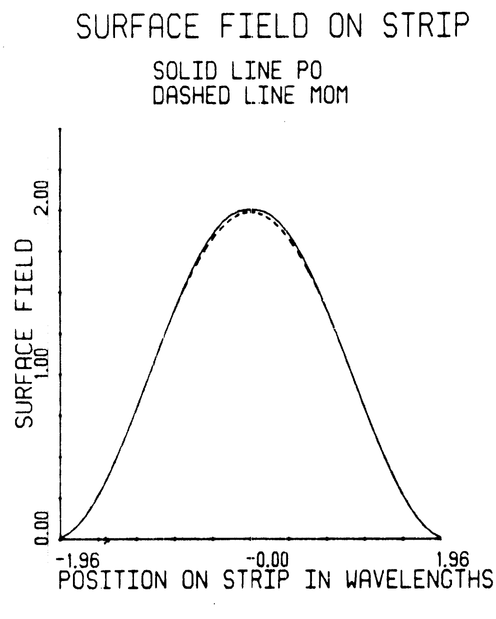

Figure 5b. Surface Field, E-polarization

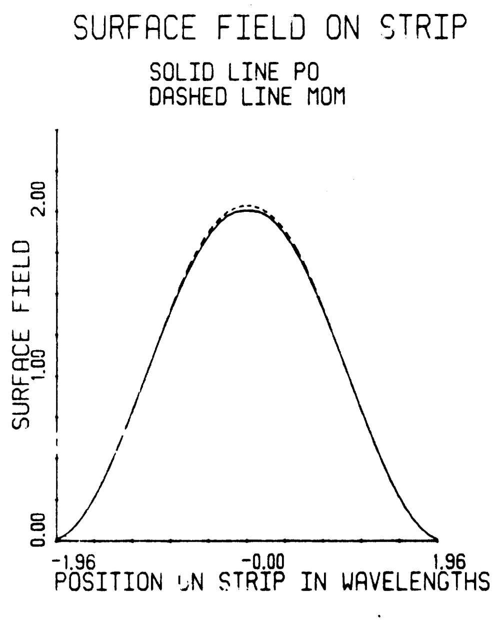

Figure 5c. Surface Field, H-polarization